SDMS US EPA Region V

Imagery Insert Form

Document ID: 177274

Some images in this document may be illegible or unavailable in SDMS. Please see reason(s) indicated below:

[X] Illegible due to bad source documents. Image(s) in SDMS is equivalent to hard copy.

Specify Type of Document(s) / Comments:

TWO PAGES OF THE CINCINNATI SOIL PROJECT NEWSLETTER; FIGURES DESCRIBED BELOW; P.3-54 COPIED OFF BALANCE SHOWING ONLY THE RIGHT SIDE OF THE PAGE; SOME PAGES IN APPENDIX J

[X] Includes _____ COLOR or __X__ RESOLUTION variations.
Unless otherwise noted, these pages are available in monochrome. The source document page(s) is more legible than the images. The original document is available for viewing at the Superfund Records Center.

Specify Type of Document(s) / Comments:

FIGS. 3-7, 4-4, 4-5, 4-6, 4-8,4-9, 4-12 THROUGH 4-24

[ ] Confidential Business Information (CBI).
This document contains highly sensitive information. Due to confidentiality, materials with such information are not available in SDMS. You may contact the EPA Superfund Records Manager if you wish to view this document.

Specify Type of Document(s) / Comments:

[ ] Unscannable Material:
Oversized ____ or ____ Format.
Due to certain scanning equipment capability limitations, the document page(s) is not available in SDMS. The original document is available for viewing at the Superfund Records center.

Specify Type of Document(s) / Comments:

[ ] Document is available at the EPA Region 5 Records Center.

Specify Type of Document(s) / Comments:

Rev. 07/10/02

United States
Environmental Protection
Agency

Office of Health and
Environmental Assessment
Washington DC 20460

[illegible]
July 1993

Research And Development

93

EPA

Urban Soil Lead Abatement Demonstration Project

Volume IV: Cincinnati Report

EPA 600/AP-93/001D
July 1993

Urban Soil Lead Abatament Demonstration Project

Volume IV: Cincinnati Report

Environmental Criteria and Assessment Office
Office of Health and Environmental Assessment
Office of Research and Development
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

FINAL REPORT

CINCINNATI SOIL LEAD ABATEMENT DEMONSTRATION PROJECT

July 1, 1993

DISCLAIMER

This document is an internal draft for review purposes only and does not constitute U.S. Environmental Protection Agency policy. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

TABLE OF CONTENTS (cont'd)

TABLE OF CONTENTS (cont'd)

LIST OF TABLES

LIST OF TABLES (cont'd)

LIST OF TABLES (cont'd)

LIST OF TABLES (cont'd)

LIST OF TABLES (cont'd)

LIST OF FIGURES

LIST OF FIGURES (cont'd)

LIST OF AUTHORS AND CONTRIBUTORS

Co-authors

Scott Clark, Ph.D., P.E., C.I.H.	
Robert Bornschein, Ph.D.	
Linda Conway-Mundew	Administration
Joanne Grote	Subject Matters
William Menrath	Abatement and Environmental Monitoring
Winkey Pan, Ph.D.	Data Analysis
Sandy Roda	Analytical Chemistry

Other Contributors

Shane Que Hee, Ph.D.	University of Cincinnati
Douglas Linz, M.D.	University of Cincinnati
Paul Succop, Ph.D.	University of Cincinnati
Barbara Poppe	University of Cincinnati
Carol Thompson	University of Cincinnati
Penny Schmitgen	University of Cincinnati
Donna Adams	Cincinnati Health Department
Denis Boudreau	Cincinnati Health Department
William Hansan	Cincinnati Health Department
Lois Betka	U.S. EPA Region V
Steve O'Strodka	U.S. EPA Region V
Pat VanLeeuwen, Ph.D.	U.S. EPA Region V
Carol Rice, Ph.D. C.I.H.	

LIST OF ABBREVIATIONS AND ACRONYMS

AAS	Atomic absorption spectroscopy
ACGIH	American Conference of Governmental Industrial Hygenists
ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
ARC/INFO	Software package supporting geographic information systems
ASTM	American Society for Testing Materials
ASV	Anodic stripping voltammetry
BMDP	Statistical software package
CDC	Centers for Disease Control
CSP	Cincinnati Soil Project
CUFS	College and University Financial System
dBASE	Database management software
dL	Deciliter, used here as a measure of blood lead in micrograms per deciliter
DMS	Data management system
Dust Loading	Mass of dust per unit area
Dustfall	Dust collected on an upfacing surface
DVM	Dust vacuum method
ECAO/RTP	Environmental Criteria and Assessment Office/ Research Triangle Park, NC
EHRT	Environmental Health Testing, Inc.
EMSL/LV	U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory at Las Vegas, NV

LIST OF ABBREVIATIONS AND ACRONYMS

FEP	Free erythrocute protoporphyrin
GIS	Geographic Information Systems
GM	Geometric mean
GSD	Geometric standard deviation
Hematocrit	Volume fraction of blood representing the cellular and other particulate matter
HEPA	High efficiency particle accumulator
IDMS	Isotope dilution mass spectrometry
IRB	Internal Review Board
LCL	Lower confidence limit
NBS	National Bureau of Standards (now National Institute for Science and Technology)
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute for Science and Technology
Nonparametric statistics	Statistical methods for noncontinuous parameters
OSHA	Occupational Safety and Health Administration
Pb	Lead
Pb Concentration	Mass of lead per mass of medium (soil, dust, water)
Pb Loading	Mass of lead per unit area
PbB	Blood lead, measured in micrograms per deciliter
ppm	Parts per million, genearlly equivalent to micrograms per gram
QA/QC	Qualtiy assurance/quality control
SARA	Superfund Amendments and Reauthorization Act

LIST OF ABBREVIATIONS AND ACRONYMS

SAS	Statistical software
SD	Standard deviation
SES	Socioeconomic status
SFe	Serum iron
SHO	Safety and health officer
SHP	Safety and health plan
SPSS	Statistical software package
Structural Equation Modeling	Model based on a system of simultaneous linear equations
SYSTAT	Statistical software package
TIBC	Total iron binding capacity
T-test	Statistical test for normal distribution
UCL	Upper confidence limit
U.S. EPA	U.S. Environmental Protection Agency
XRF	X-ray fluorescence
ZPP	Zinc protoporphyrin

1. EXECUTIVE SUMMARY

1.1 INTRODUCTION

In late 1987 Cincinnati was selected to be the location of one of three urban Soil Lead-Abatement Demonstration Projects to implement Section 111(b)(6) of the Superfund Amendment and Reauthorization Act (SARA) of 1986. This project was conducted by investigators in the Department of Environmental Health at the University of Cincinnati in collaboration with the City of Cincinnati Department of Health. The Cincinnati project made use of extensive experience in the Department of Environmental Health in pediatric lead exposure studies. The Cincinnati project was conducted in neighborhoods where most of the housing had lead-based paint removed about two decades earlier as a result of a complete rehabilitation carried out under U.S. Housing and Urban Development-supported programs. The rehabilitation involved a "gutting" of the buildings and the complete replacement of plumbing, wiring and heating systems and the installation of new walls, flooring, windows and doors. Exterior brick areas were either sandblasted or chemically cleaned and sometimes were re-painted. Most of the rehabilitated buildings were 3 to 4 story multi-family structures and all were rental units. Soil in these neighborhoods was located primarily in small parks, recreational areas and vacant lots and not specifically part of the same property containing the rehabilitated housing. Therefore, in order to include all of the soil areas in the abatement project the decision was made early in the project design to abate entire neighborhoods. Thus, all soil areas in the neighborhoods were included, whether or not there were housing units on the property. This neighborhood-wide design, rather than the scattered house approach used elsewhere, was extended to include exterior surface dust on paved areas. Therefore, a neighborhood-wide paved surface cleaning was also performed.

The two central hypotheses of this project were that:

(1) A reduction of lead in residential soil accessible to children would result in a decrease in their blood-lead levels, and

(2) Interior dust abatement, when carried out in conjunction with exterior dust and soil abatement, would result in a greater reduction in blood lead than would be obtained with interior dust abatement alone, or exterior dust and soil abatement alone.

A secondary hypotheses was that:

(3) A reduction of lead in residential soil accessible to children will result in a decrease in their hand lead levels.

1.2 METHODS

Three areas, designated A, B and C, were selected for the study. A door-to-door census was performed to determine the availability of an adequate number of children less than six years of age. A preliminary soil lead survey was also undertaken to provide baseline soil lead values and to document the presence of lead-contaminated soil. The choice of which neighborhoods to include was made on the basis of the census and preliminary soil lead survey. During the 1989 abatement period Area A received interior and exterior dust abatement and soil abatement, while Area B received interior dust abatement only. Exterior dust and soil abatement were performed in Area B during the summer of 1990 and all three abatements were performed in Area C after the last sampling phase in 1991.

The soil abatement plan involved removal of the top six inches of soil when either the average or the top 2 cm lead concentrations was ≥500 ppm, replacement with low lead soil (<20 ppm) and resodding. In areas where the grass cover was poor and the surface concentration was ≥300 ppm, removal, replacement and resodding also was performed. Available vacuum-based street cleaning equipment was tested to determine which equipment was capable of removing greater than 90% of the dust from rough paved surfaces. Extensive testing of high efficiency particle accumulator (HEPA) vacuum cleaning of lead-dust containing carpets was conducted. Based on the results of these tests, and tests of new carpets embedded with dust in the laboratory, it was concluded that carpets could not be satisfactorily cleaned. Substantial amounts of lead remained in the carpets after repetitive cleaning and, in a number of cases, the lead dust loading on the surface was increased during the vacuum cleaning. Therefore, carpet replacement was selected as the method of choice for dealing with existing carpets. Based on the carpet cleaning experience and a limited amount of testing of cleaning methods for upholstered furniture, it was concluded that contaminated upholstered furniture should also be replaced to the extent possible.

Environmental monitoring was performed during ten sampling phases before and after the various abatement procedures were conducted. The types of environmental samples collected and the number of times such samples were collected during a three-year period are as follows: soil (seven times), exterior dust (seven times), interior dust (seven times), and paint and water (once). Blood samples were collected from participants five times and hand wipes seven times. Interior surface dust samples were collected with a vacuum procedure that we had previously developed using a portable pump designed for collecting personal air samples. These samples were collected at the interior apartment entry, on a door mat that was supplied to the participants and on a composite of interior floor areas and on a composite of window sill areas. The exterior surface dust samples were collected with a battery-operated "auto-vac" at the exterior entry to the housing of study participants and on paved areas (streets, alleys, sidewalks, parking lots, etc.) throughout the study neighborhoods. Buffer areas, extending for about one block in all directions outside the recruitment areas, were also included in the exterior dust abatement. This was done in an effort to delay the recontamination of paved areas from adjacent unabated paved areas.

1.3 RESULTS

A total of 307 children were involved in the study including 291 recruited during the two recruitment efforts and 16 children who were born to study families during the study. The focus of the study was on 173 children less than six years of age who lived in rehabilitated housing and who were in the initial recruitment (Spring, 1989).

The number of blood and hand wipe samples collected was 1,367 and 8,127, respectively, 2,407 exterior dust, 3,332 interior dust, 8,127 soil and 324 water samples were collected and analyzed. In addition, 580 X-ray fluorescence (XRF) in situ paint lead determinations were also performed.

1.3.1 Soil Lead

The geometric mean soil lead in top 2 cm cores in Area A decreased from 200 ppm preabatement to 54 ppm postabatement. The 95 percentile value decreased by over 2,200 ppm (from 2,659 to 422 ppm). In Area B the geometric mean decreased from 161 to 60 ppm and the 95% value decreased from 1,509 to 249 ppm, a drop of 1,260 ppm. In all areas soil lead concentrations in lots adjacent to buildings were much higher than in other lots. For example, in preabatement samples in Area A, the geometric mean and 95 percentile concentration were 201 and 2,856 ppm, respectively, near buildings while they were 93 and 579 ppm, respectively, in other lots.

1.3.2 Exterior Dust Lead

In Area A the exterior dust lead loading (mg Pb/m^2) was 260 ppm before abatement and 257 ppm after abatement in the buffer areas. In the nonbuffer areas (center portion of study area) the loading was reduced slightly from 419 to 347. In Area B the first postabatement dust sample was collected within about 24 h of the abatement, a somewhat shorter time period than for Area A the previous year, in an attempt to get a clearer indication of the abatement impact. For one of the neighborhoods in Area B the lead loading decreased in the buffer area by 48% and in the non-buffer area by 63%. In the other Area B neighborhood, the decreases were 59 and 72%, respectively. Exterior dust lead loadings in the exterior housing entry area decreased in Area A from about 230 mg/m^2 preabatement to about 100 mg/m^2 postabatement but increased to preabatement levels about 4 mo later.

1.3.3 Interior Dust Lead

Interior entry dust lead loadings in Area A decreased from 387 $\mu g\ Pb/m^2$ preabatement to 230 $\mu g/m^2$ in the first postabatement sample. Lead loading remained at this level in samples collected about four months later but increased to preabatement levels about 10 mo after abatement. In Area B interior entry lead dust loadings decreased to about 2/3 of preabatement levels in the first postabatement samples and increased slightly four months later. In the sample collected about 10 mo postabatement, however, they increased to several times preabatement levels. Dust lead loadings in composite floor samples from Area A decreased from 188 $\mu g/m^2$ preabatement to 76 $\mu g/m^2$ postabatement, a decrease of about 60%. They remained at that same level in samples collected about four months postabatement and were 35% below preabatement levels in samples collected 10 mo postabatement. In Area B, geometric mean dust lead loadings in composite floor samples were 138 $\mu g/m^2$ preabatement and were 81% lower in the first postabatement sample and 62% lower in samples collected four months postabatement. However, by ten months postabatement the mean value had increased to well above the preabatement level.

1.3.4 Blood Lead

Following interior and exterior dust and soil lead abatement, blood lead concentrations decreased in Area A from 8.9 to 7.0 (21%) but increased to 8.7 10 mo postabatement. In Area B (interior dust abatement only) blood lead concentrations decreased from 10.6 to 9.2 (13%) 4 mo postabatement and were 18% below preabatement levels 10 mo postabatement. However, blood lead levels in Area C (no abatement) also decreased by 29% and 6% during these same time periods. Other comparisons also revealed no effects of the soil or dust abatement.

1.3.5 Hand Lead

A comparison of the geometric mean hand lead in the first postabatement sample with the preabatement sample revealed a decrease of 0.92 μg Pb in Area A, an increase of 0.14 μg Pb in Area B and an increase of 0.41 μg Pb in the control group C. Four months postabatement the geometric mean hand lead was 1.49 μg below preabatement in Area A, 0.74 below in Area B and 0.68 below in control Area C. In the samples collected 10 mo postabatement, geometric mean hand lead levels were much higher than preabatement levels in all areas. Other comparisons before and after the exterior dust and soil abatement in Area B in 1990 also did not reveal any potential effects of the abatement.

1.3.6 Intercorrelation Among Environmental Lead Measures and Blood Lead

Correlations between blood lead and hand lead, or interior dust lead (ppm and $\mu g/m^2$) or exterior dust (ppm) were observed as they were in an earlier study of children in the same neighborhoods but with a wider range of housing types. Similarly, correlations were observed between hand lead and interior and exterior dust lead and between interior and exterior dust lead. Correlations involving paint lead were not significant probably because of the very low levels and narrow range of paint lead in the abatement project.

1.3.7 Environmental Dust Lead Levels

Geometric mean concentrations of lead in exterior dust ranged from 416 ppm (Area C) to 2,119 ppm (Area A) in samples collected at the entry areas of the housing of study participants. Mean exterior dust lead loadings ranged from 88 mg/m^2 to 225 mg/m^2. In street, sidewalk and alley samples, mean levels ranged from 829 to 2,216 ppm and 231 to 534 mg/m^2. Mean dust lead in interior entry samples ranged from 261 to 559 ppm and 150 to 387 $\mu g/m^2$.

1.3.8 Abatement Costs

Average soil abatement costs (including removal, disposal, replacement and resodding) were $\$35/m^2$ in 1989, $\$27/m^2$ in 1990 and $\$32/m^2$ in 1991. Interior dust abatement costs, including carpet replacement and the limited replacement of upholstered furniture, were $\$16/m^2$ in 1989, $\$18/m^2$ in 1990 and $\$13/m^2$ in 1991. The interior dust abatement costs may also be expressed on a per housing unit basis, $1,212 in 1989, $1,477 in 1990 and $1,124 in 1991. Exterior dust abatement costs were $\$0.97/m^2$ in 1989 and $0.89 in 1990. On a per study participant basis, average abatement costs, as a percent of the total for all three abatements, were 56% for soil, 26% for interior dust and 23% for exterior dust.

1.4 CONCLUSIONS

Soil lead abatement was achieved and there was no evidence for soil recontamination over the period of measurement (up to about two years).

While some evidence of exterior dust abatement was found, its impact was often not evident at the next sampling phase (one to 3 mo later). Recontamination of paved areas often occurred immediately after exterior dust abatement.

2. BACKGROUND

In late 1987 Cincinnati was selected to be the location of one of three urban Soil Lead-Demonstration Projects to implement Section 111(b)(6) of the Superfund Amendment and Reauthorization Act (SARA) of 1986. This project was conducted by investigators in the Department of Environmental Health at the University of Cincinnati in collaboration with the City of Cincinnati Department of Health. The Cincinnati project was conducted in neighborhoods where most of the housing had previously been lead-based paint-abated about two decades earlier as a result of a complete rehabilitation carried out under U.S. Housing and Urban Development-supported programs. The rehabilitation involved a "gutting" of the buildings and the complete replacement of plumbing, wiring and heating systems and the installation of new walls, flooring, windows and doors. Exterior brick areas were either sandblasted or chemically cleaned and sometimes were re-painted. Most of the rehabilitated buildings were 3-4 story multi-family and all were rental units. Soil in these neighborhoods was generally located primarily in small parks, recreational areas and vacant lots and not specifically part of the same property containing the rehabilitated housing. Therefore, in order to include all of the soil areas in the abatement project the decision to include entire neighborhood areas was made early in the project design. Thus all soil areas in the study areas were included, whether or not there were housing units on the property. This neighborhood-wide design, rather than the scattered house approach used elsewhere, also allowed us to perform a neighborhood-wide paved surface cleaning.

2.1 HYPOTHESES

The two central hypotheses of this project were that:

(1) A reduction of lead in residential soil accessible to children would result in a decrease in their blood-lead levels, and

(2) Interior dust abatement, when carried out in conjunction with exterior dust and soil abatement, would result in a greater reduction in blood lead than would be obtained with interior dust abatement alone, or exterior dust and soil abatement alone.

Secondary hypotheses were that:

(3) A reduction of lead in residential soil accessible to children will result in a decrease in their hand lead levels, and

(4) Interior dust abatement, when carried out in conjunction with exterior dust and soil abatement, would result in a greater reduction in hand lead than would be obtained with interior dust abatement alone, or exterior dust and soil abatement alone.

The specific questions to be answered in the Cincinnati Soil-Lead Abatement Demonstration Project were as follows:

- Does interior dust abatement in rehabilitated (including lead-based paint abated) housing in conjunction with soil-lead and exterior dust abatement, or interior dust abatement alone, result in the reduction of blood lead (PbB) in children relative to children living in rehabilitated housing in the control area where no abatement occurs?

- Does soil or dust abatement result in a covariate adjusted reduction in PbB relative to each child's pre-abatement PbB?

- Does exterior abatement (exterior dust and soil) result in a significant reduction in PbB relative to that in children in housing where no abatement occurs?

- Is the reduction in PbB and environmental lead transient or long term?

Secondary objectives were to:

- determine the effectiveness of the abatement procedures in reducing the quantity of lead-contaminated dust in residences;

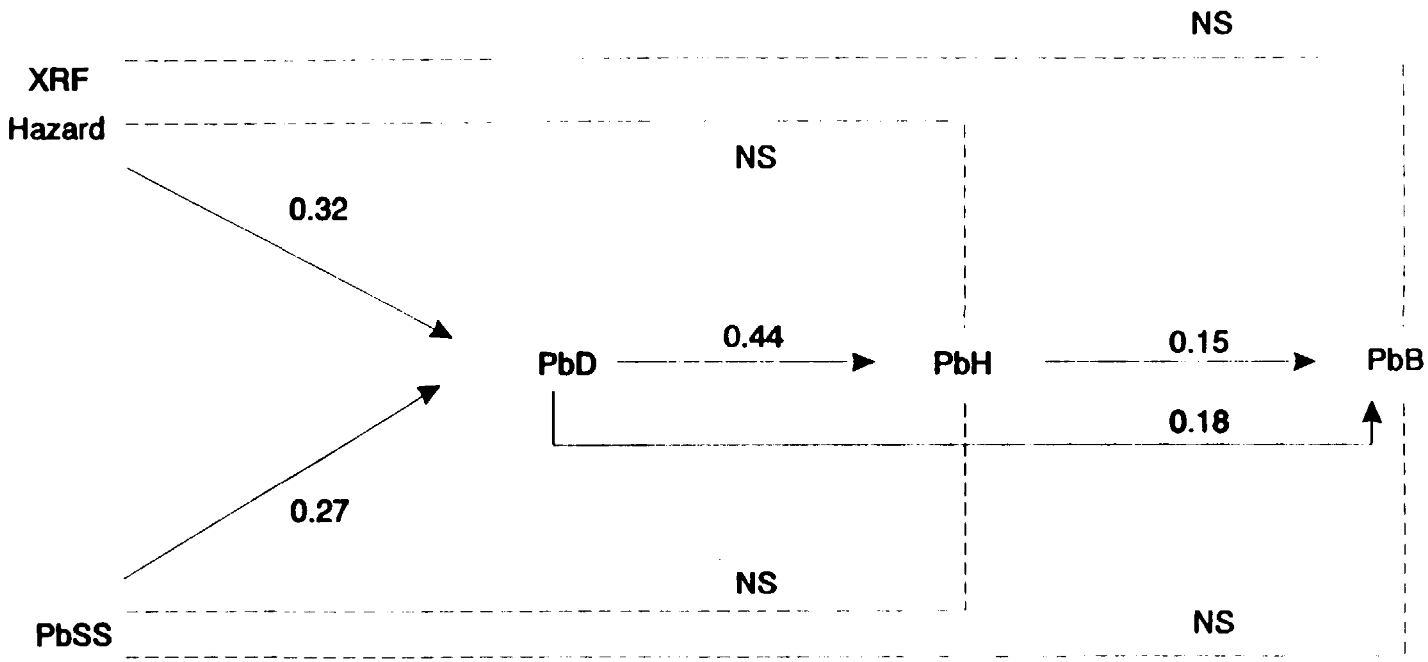
- determine the rate of reaccumulation of household dust-lead;

- determine the factors associated with household dust-lead reaccumulation; and to

- estimate the rate of exterior and interior recontamination.

2.2 PREVIOUS RELATED WORK

An ongoing study of childhood lead poisoning (Bornschein et al., 1985 and Clark et al., 1991) led to the development of a causal model (Figure 2-1) that demonstrated the existence of a lead exposure pathway leading from lead in external soil/dust adjacent to housing units



Structural Equations: $\underline{R^2}$

Ln(PbB) = 1.276 + 0.152 Ln (PbH) + 0.182 Ln (PbD) 0.38

Ln(PbH) = 0.966 + 0.444 Ln (PbD) 0.22

Ln(PbD) = 4.691 + 0.325 Ln (XRFHAZ) + 0.268 Ln (PbSS) 0.52

All coefficients are significant at $p < 0.05$; NS=Not Significant

Figure 2-1. Reduced structural model for pathway from environmental lead to blood lead for 18 mo old.

Source: Bronschein et al. (1986).

(PbSS) and paint lead (XRF) to interior house dust (PbD), then to hand lead (PbH) and ultimately to blood lead (PbB). This pathway suggested that an intervention strategy involving control of exterior dust/soil, paint, and interior dust could potentially lead to statistically significant reductions in blood lead. Contaminated soil serves as one of the lead reservoirs that contributes to external dust on the street and other areas in or near housing units. The reduction in soil lead in areas where the house paint lead has already been thoroughly abated would, therefore, lead to a reduction in exterior dust lead and consequently interior dust lead, hand lead and ultimately blood lead. However, because of the existing accumulations of exterior and interior dust lead in the housing environment, the impact on blood lead reduction of soil lead abatement alone would be delayed and reduced if dust lead abatement did not also occur. The Cincinnati Soil-Lead Abatement Demonstration Project was therefore designed to evaluate three abatement components suggested by the causal model to be significantly linked to elevated blood lead levels:

Soil Lead abatement
Exterior dust abatement
Interior dust abatement

The impact of existing paint lead was not expected to interfere with the evaluation of the effectiveness of soil and dust lead abatement if the focus was on lead-paint free rehabilitated housing units. Cincinnati fortunately has a large stock of about 6,000 residential housing units, available to low and moderate income families, that have been completely rehabilitated and deleaded under various U.S. housing programs, mainly during the late 1960's and early 1970's.

Blood lead profiles of children up to 42 mo of age living in rehabilitated housing units (low paint lead), public housing (also containing only very low levels of paint lead), newer post World War II housing (low paint lead), and 19th century private housing units (multiple sources of lead), that are in deteriorated/dilapidated or satisfactory condition (by exterior evaluation) are shown in Figure 2-2. The children with the lowest PbB reside in the post World War and public housing, while those in the deteriorated housing, not unexpectedly, have the highest PbB values. What was surprising from the data in Figure 2-2, however, was that children residing in the rehabilitated housing had PbB values much higher than those in public housing, higher by about 10 $\mu g/dL$ at 18 mo of age, even though paint lead levels

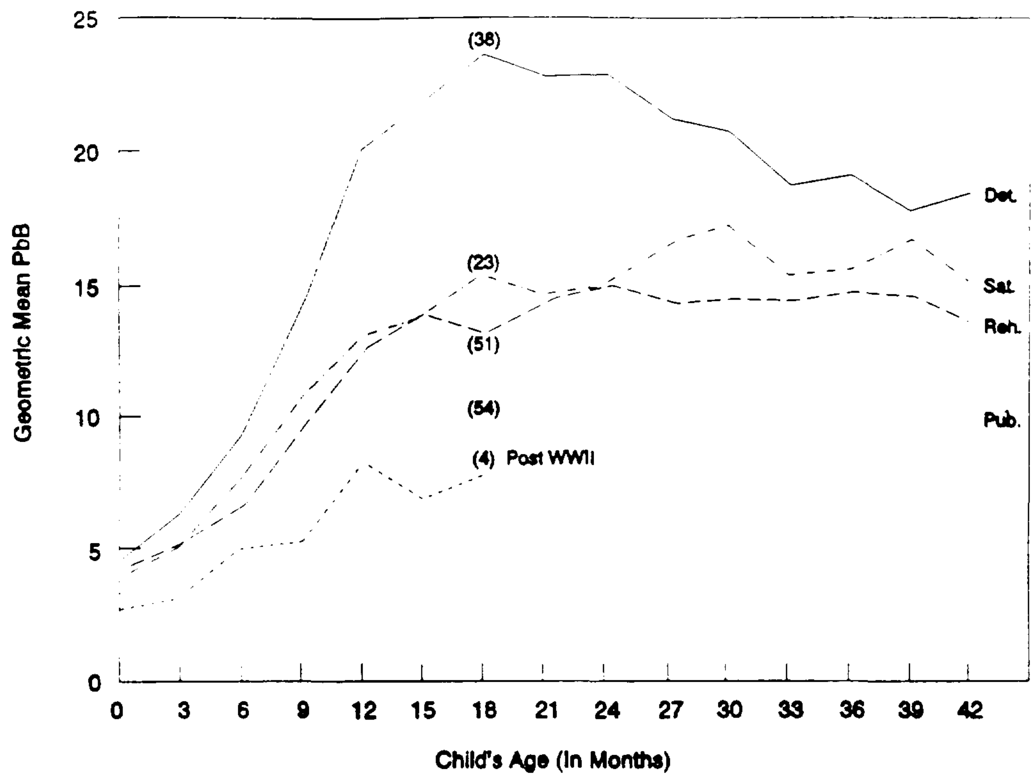


Figure 2-2. Effect of housing type and condition on early childhood blood lead concentrations.

Source: Clark et al. (1988).

were equally low in both housing categories (Table 2-1). Blood lead levels of children living in the rehabilitated housing were similar to those living in satisfactory housing that had not been rehabilitated. The higher than expected PbB of children in rehabilitated housing appeared to be due to the fact that most of the rehabilitated housing was intermixed in neighborhoods with non-rehabilitated housing, frequently in a poor state of repair, which resulted in much higher interior and exterioı dust lead levels in rehabilitated housing than in public housing (Table 2-1). Being in close proximity to housing with lead paint, the rehabilitated housing became contaminated by lead-contaminated dusts which migrated to the areas immediately outside and within the rehabilitated units. This project offered the opportunity to test the hypothesis that the blood lead levels of children living in rehabilitated and satisfactory housing could be reduced by reducing lead levels in soil and dust in the areas in which housing is located.

TABLE 2-1. ENVIRONMENTAL LEAD MEASURES BY HOUSING TYPE

Environmental Lead Measure[a]	Post-2nd WW Private Satisfactory Condition	Public Housing	Subsidized Rehabilitated Housing	19th Century Satisfactory Condition Private (non-rehab.)	19th Century det./dilap.[b] (non-rehab.)
Paint (ppm)	d				
Mean		2,750	2,820	30,500	25,200
(±1 SD)	-	(477-15,900)	(85-93,900)	(3,600-254,000)	(4,500-142,000)
n[c]	-	16	11	37	108
XRF (mg cm^{-2})					
Mean	1.2	1.7	1.2	7.3	10.5
(±1 SD)	(0.4-3.4)	(0.9-3.4)	(0.5-3.0)	(2.5-21.1)	(5.0-22.0)
n	51	112	111	92	163
Paint hazard[e]					
Mean	0.4	1.0	0.6	4.7	9.7
(±1 SD)	(0.1-1.4)	(0.4-2.4)	(0.2-1.7)	(1.2-19.1)	(3.2-29.0)
n	51	112	111	92	163
Interior surface dust (ppm)					
Mean	332	490	622	1,680	2,360
(±1 SD)	(151-733)	(242-996)	(289-1,340)	(586-4,800)	(957-5,840)
n	44	95	101	84	146
Interior surface dust (mg m^{-2})					
Mean	0.13	0.25	0.25	0.77	2.1
(±1 SD)	(0.04-0.43)	(0.09-0.72)	(0.07-0.93)	(0.13-4.72)	(0.46-9.50)
n	44	95	99	81	141

TABLE 2-1 (cont'd). ENVIRONMENTAL LEAD MEASURES BY HOUSING TYPE

Environmental Lead Measure[a]	Post-2nd WW Private Satisfactory Condition	Public Housing	Subsidized Rehabilitated Housing	19th Century Satisfactory Condition Private (non-rehab.)	19th Century det./dilap.[b] (non-rehab.)
Interior dustfall (ppm)					
Mean	176	179	221	464	563
(±1 SD)	(55-567)	(53-612)	(67-727)	(136-1,590)	(174-1,820)
n	45	97	101	75	127
Interior dustfall (μg/m^{-2}/ 30 days)					
Mean	0.035	0.054	0.075	0.139	0.199
(±1 SD)	(0.011-0.116)	(0.16-0.181)	(0.024-0.234)	(0.029-0.653)	(0.047-0.841)
n	45	97	99	75	127
Exterior surface scraping (ppm)					
Mean	327	233	1,800	5,000	4,550
(±1 SD)	(118-905)	(87-622)	(611-5,280)	(1,430-17,500)	(1,180-17,600)
n	21	67	81	45	96
Soil core (ppm)					
Mean	98	138	221	692	905
(±1 SD)	(37-264)	(67-284)	(59-826)	(259-1,840)	(384-2,130)
n	23	38	13	29	29

3. STUDY DESIGN AND METHODS

3.1 OVERALL DESIGN

The Cincinnati Project involved the selection of three areas (A, B, and C) with a predominance of lead-based paint abated (rehabilitated) housing and with an adequate number of children up to five years of age.

The schedule of environmental and biological monitoring and for abatement for each of three study areas is outlined in Figures 3-1 and 3-2. Area A received all three abatement treatments (lead, exterior dust and interior dust) in 1989. Area B received interior dust abatement in 1989 and exterior abatement (soil and dust) in 1990 and the control Area C received all three abatements in 1991. Environmental and biological monitoring was conducted at a total of 9 times before and after each abatement cycle except that no monitoring was performed after the 1991 abatement in control Area C.

3.2 NEIGHBORHOOD AND SUBJECT SELECTION, RECRUITMENT AND RETENTION

As mentioned earlier, the design of the Cincinnati project involved the selection of multi-block areas where the predominant type of housing was that which had previously undergone extensive "gut" rehabilitation with the removal or encapsulation of most of the lead-based paint areas. Therefore, a neighborhood area selection process was used which required a complete census of all property owners and residents and an initial soil sampling survey. This was needed to determine if there was an adequate number of children less than six years of age (about 50 per study area) and accessible soil with elevated lead concentration (greater than or equal to 500 ppm). The procedure for calculating the sample size required is presented in Appendix A.

3.2.1 Enrollment Criteria

Selection of several study areas with similar characteristics was important in order to determine the impact of the exterior and interior lead abatement procedures. This was

Figure 3-1.

ABATEMENT AND MONITORING TIME TABLE

Year 1 - 1988 Soil Pb Surveys, Methods Development, Pilot Testing of Abatement September - December (Phase 0) Methods, Training, and Negotiation with Property Owners				
Year 2 - 1989 January - May	Continuation of Above			
	Area A	Area B	Area C	
June/July	M[a]	M	M	(Phase 1)
August/ September	abate soil exterior dust interior dust	abate interior dust	no abatement	
September/ October	EM[b]	EM	EM	(Phase 2)
November	M	M	M	(Phase 3)
Year 3 - 1990				
February	P/W M[c]	P/W M	P/W M	(Phase 4)
June	M	M	M	(Phase 5)
August	no abatement	abate soil[d] and exterior dust	no abatement	
September	EM	EM	EM	(Phase 6)
November	M	M	M	(Phase 7)
Year 4 - 1991				
February	P/W M	P/W M	P/W M	(Phase 8)
June	M	M	M	(Phase 9)
July/August	no abatement	no abatement	abate soil, exterior dust, interior dust	
July - December	Sample and data analysis			
Year 5 - 1992	Complete sample and data analysis and [illegible]port writing			

[a]M = Monitoring: Blood Lead, Hand Lead, Interior and Exterior Dust Lead and S[illegible] Lead.
[b]EM = Environmental Monitoring: Hand Lead, Dust Fall Interior and Exterior Dust Lead.
[c]P/W M: Pant and Water Monitoring.
[d]In other areas sampled during the initial soil surveys but not selected for the study, necessary soil abatement in public areas occurred during 1990.

Figure 3-2.

BLOOD AND ENVIRONMENTAL SAMPLE COLLECTION

	Sampling Phase									
Sample	00	01	02	03	04	05	06	07	08	09
Blood		X		X		X		X		X
Hand Lead		X	X	X		X	X	X		X
Soil										
Surface Scraping	X		X	X		X	X	X		
Top 2 cm Areas	X[a]		X[a]	X		X	X	X		X
Bottom 2 cm Areas	X		X	X		X	X	X		
Exterior Dust										
Neighborhood		X	X	X		X	X	X		
House-Targeted		X	X	X		X	X	X		X
Interior Dust										
Entry		X	X	X		X	X	X		
Floor		X	X	X		X	X	X[b]		
Window		X	X	X		X	X	X[b]		
Dustfall			X				X			
Mat		X	X	X		X	X	X[b]		X[b]
Paint					X				X[c]	
Water					X				X[c]	

[a]Initial samples for Dandridge neighborhood of Area B were collected during Phase 02.
[b]Collected but not analyzed.
[c]Phase 08 samples collected only from housing not sampled during Phase 04.

accomplished by selection of several areas within the potential study neighborhoods where socioeconomic and ethnic backgrounds were similar. Other matching variables considered included housing type, age of child, prior housing history, season, soil availability per block (group match) and percent non-rehabilitated housing per block (group match).

In order to maximize the potential impact of soil-lead abatement on lead (PbB) reduction, several features of the study area were sought. These included: a high percentage of completely rehabilitated housing (largely free of lead-based paint) and a high percentage of young children exposed to accessible, lead-contaminated, soil.

3.2.2 Initial Soil Survey

An initial soil survey was completed in order to determine the concentration of soil-lead in the proposed study areas. Soil-lead distribution was one of the criteria used in the final selection of the project study areas. This information was also necessary for the development of the abatement plans.

At the time of the initial soil survey, November 1988 through April 1989, there were six neighborhoods being considered for inclusion as part of the Cincinnati Soil Project's proposed study areas. One of the original neighborhoods under consideration was dropped after the census because of an insufficient number of children and another neighborhood was added in the Spring of 1989. The six neighborhoods were combined to make up the three study areas, Area A, Area B, and Area C.

The initial soil survey began with the identification of all soil sites in the neighborhoods under consideration for inclusion in the study areas. This was accomplished by first defining the neighborhoods on Sanborne maps. (These are large scale, 1" = 100', city maps which show streets, building outlines and approximate property lines.) The next step was to visit each study area to visually locate all soil sites and rehabilitated housing. Soil areas and rehabilitated housing units were then coded on the Sanborne maps. Two separate teams of individuals independently surveyed, on foot, each neighborhood for housing and soil sites. Any discrepancies between the surveys results were field checked by project managers.

At the conclusion of the field surveys, the locations of the soil sites on the Sanborne maps were compared with plat maps from the Hamilton county Auditor's Office in order to determine the book, page and parcel number of each property within the neighborhood. It was necessary to make this determination of book, page and parcel in order to find the name and address of the owner of each soil site and each property where other types of abatement would occur.

The property owners consisted of two groups; private owners and public owners. To obtain permission to sample soil on the privately owned sites, all owners, including individuals and corporations, were contacted by letter. Approximately 15% of the owners responded to the letter. The owners who did not respond were contacted by Soil Project staff members. A small percentage of the owners who were contacted refused to grant permission to sample soil. In one case the property was involved in litigation. In other instances, the owners were apprehensive of the consequences.

Verbal permission to sample soil was acceptable, according to the Risk Management Office of the University of Cincinnati Medical Center, if we followed certain rules. Those rules were:

- Dates and times of phone contact were recorded.
- Notes were made of phone conversations.
- Only a small number of approved individuals could make owner contact.

A significant amount of property with soil, approximately 20% in the study areas, was owned by the City of Cincinnati. A right of entry agreement between the City of Cincinnati and the University of Cincinnati was required prior to sampling soil on city-owned property. In order to process the right of entry agreements we had to make the initial request of the city government department responsible for each parcel of property. Those departments were the Recreation Commission, Parks Department, Engineering and Public Works, and Neighborhood Housing and Conservation. Once the individual department approved, the City Solicitor approved the document as to form, and finally the City Manager signed the document. The right of entry document then had to be approved by five separate offices at the University of Cincinnati and signed by a University contracting officer.

After the identification of the soil locations and necessary permission to sample was obtained, a sampling plan was completed for each soil site. The technicians who were to collect the soil were trained in the collection protocol and appropriate health and safety issues.

The initial soil survey was begun in December of 1988 and completed by April 15, 1989, with the majority of sites having been sampled by March 1, 1989. Soil samples were collected by the environmental monitoring teams and sieved at the temporary field office at 1400 State Avenue. The sieved samples were sent to the Kevex (XRF) Soil Lab at the University of Cincinnati Medical Center, where they were analyzed to provide preliminary data for characterizing the lead content in the soils in the potential study areas. Later in the study, these samples would be reanalyzed, after the recalibration of the Kevex (XRF), for a final determination of soil-lead concentration.

The initial soil survey was completed and the data were used to formulate the abatement plans for the soil abatement which occurred in the summer of 1989 and two subsequent summers of the project.

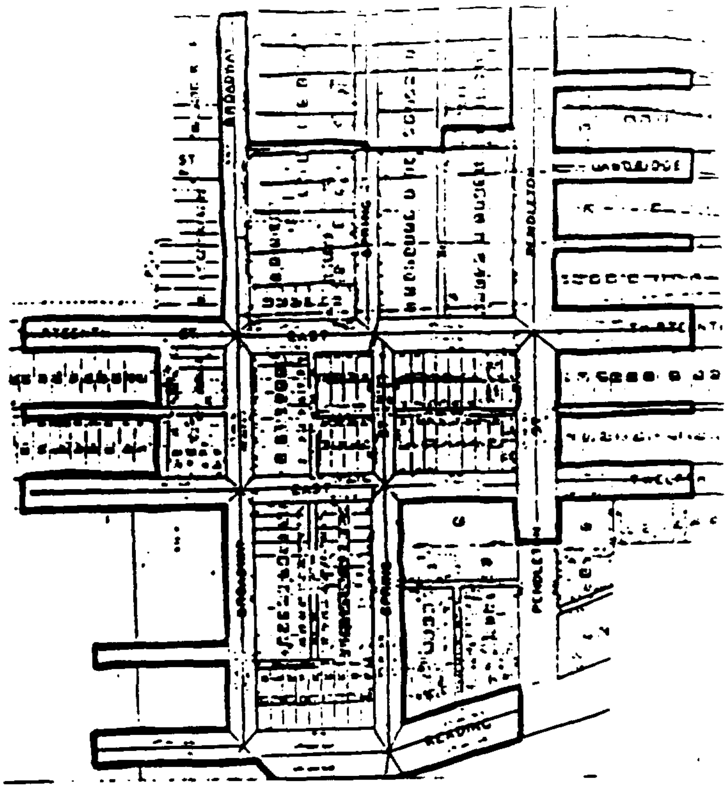
3.2.3 Identification of Study Areas

To determine which neighborhoods were appropriate for the study, project staff conducted an extensive door-to-door census to obtain information about age of children, housing types and condition of housing. Two-person teams canvassed several neighborhoods to identify potential study areas. After careful evaluation of the census data, three areas were selected for the soil-lead abatement project. Each area had 40 to 60 children under five years of age, with most living in rehabilitated housing. Areas were also similar with respect to the percentage of surface area that consisted of soil (average = 24%; range = 20 to 27%). The three study areas, A, B and C, each consisted of about 5-6 blocks of buildings, paved areas and soil areas. Area A was completely contiguous. Area B consisted of three non-contiguous sub-areas, referred to as neighborhoods: Findlay, Back and Dandridge. Area C consisted of two non-contiguous neighborhoods: Glencoe and Mohawk. (Soil sampling data presented later in this report revealed that the areas were comparable in lead concentration with Area B and C being practically equivalent and A only moderately higher). Maps of the individual study neighborhoods appear in Figures 3-3, 3-4, and 3-5. The location of each of these neighborhoods is presented in Figure 3-6.

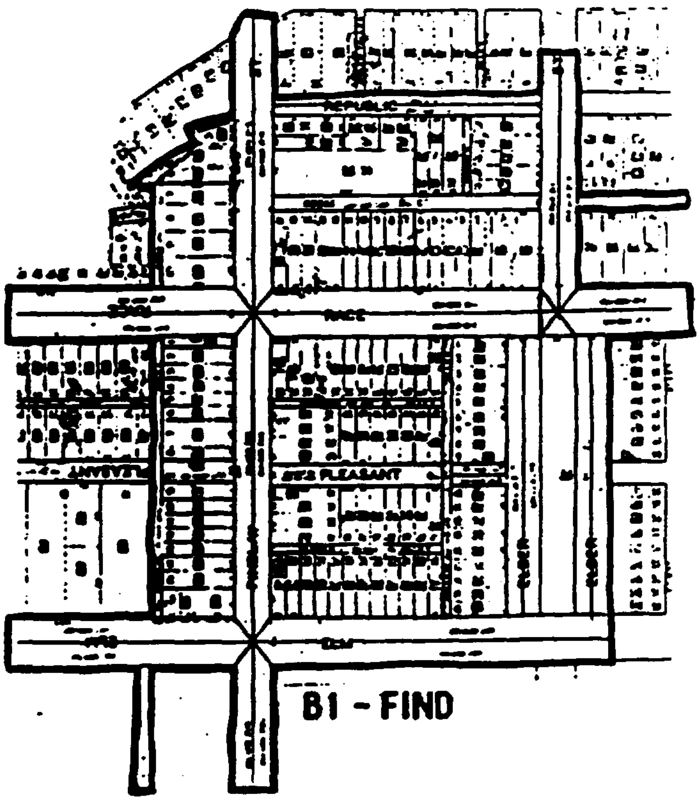
3.2.4 Participant Enrollment Procedures

In the Spring of 1989, individual letters were sent to prospective study families within the identified neighborhoods. A fact sheet describing the study and the benefits of participation was also included in this mailing (see Appendix B). Shortly after the mailing of the study announcement, recruitment teams, consisting of two persons, visited each family to personally invite them to participate in the soil-lead abatement project. At this visit, a brief description of lead poisoning in children was given and why participation in the project could benefit the community in general and their children in particular.

In addition, if the family agreed to participate, a written appointment reminder for blood collection was given to the caregiver, along with notification that a fixed transportation

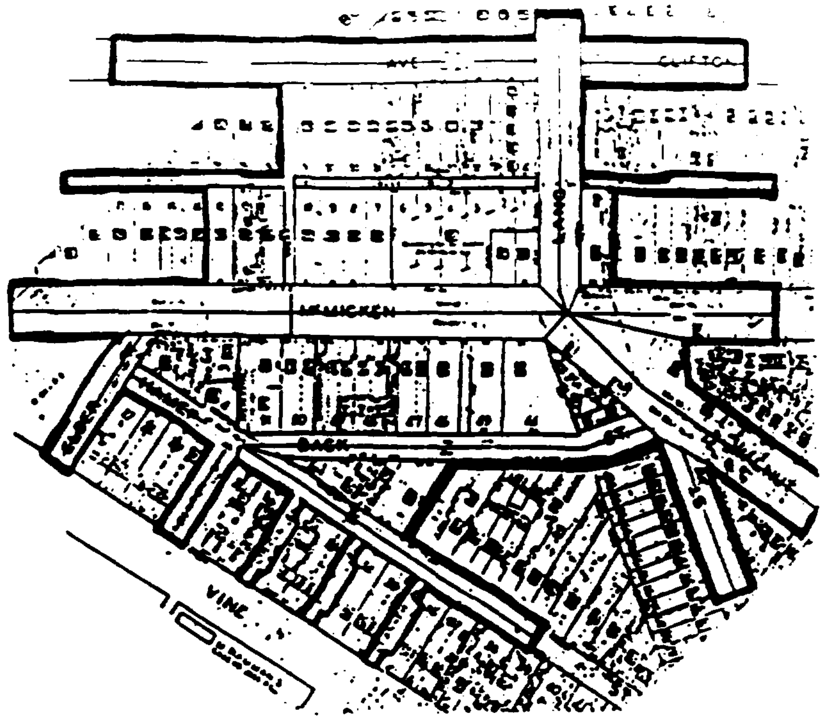


A - PEND

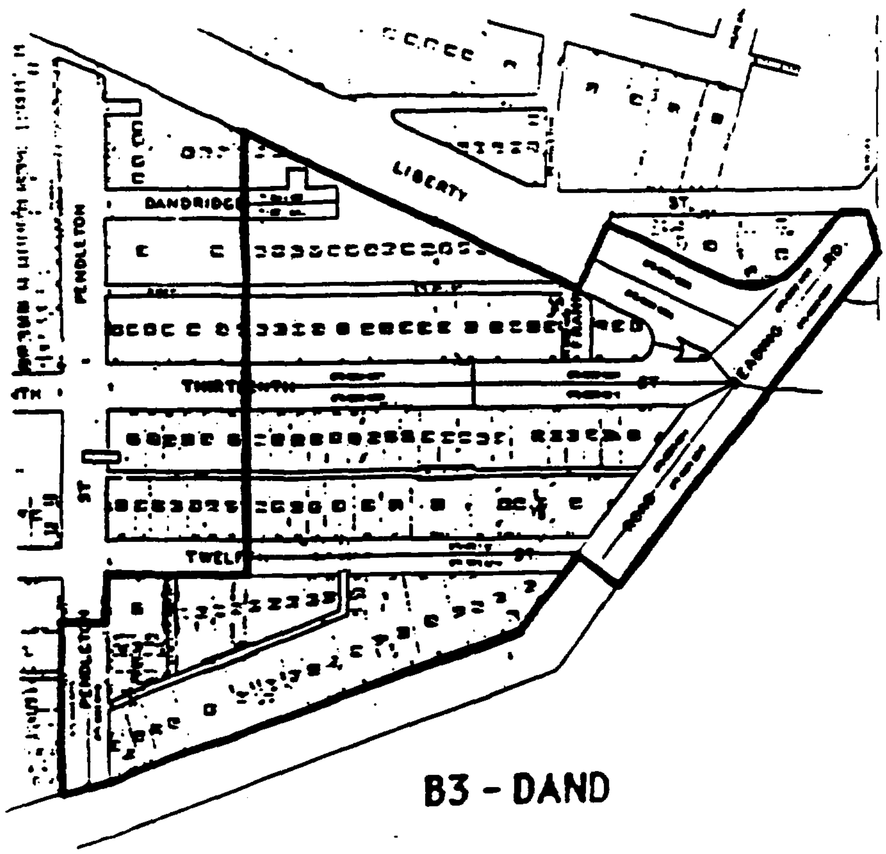


B1 - FIND

Figure 3-3. Schematic diagrams of the Pendleton (Area A) and Findlay (Area B) neighborhoods.

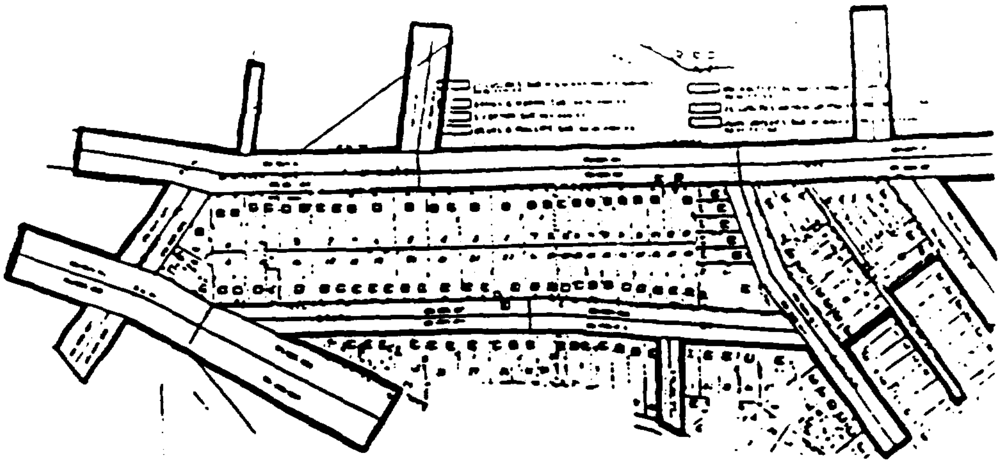


B2 - BACK

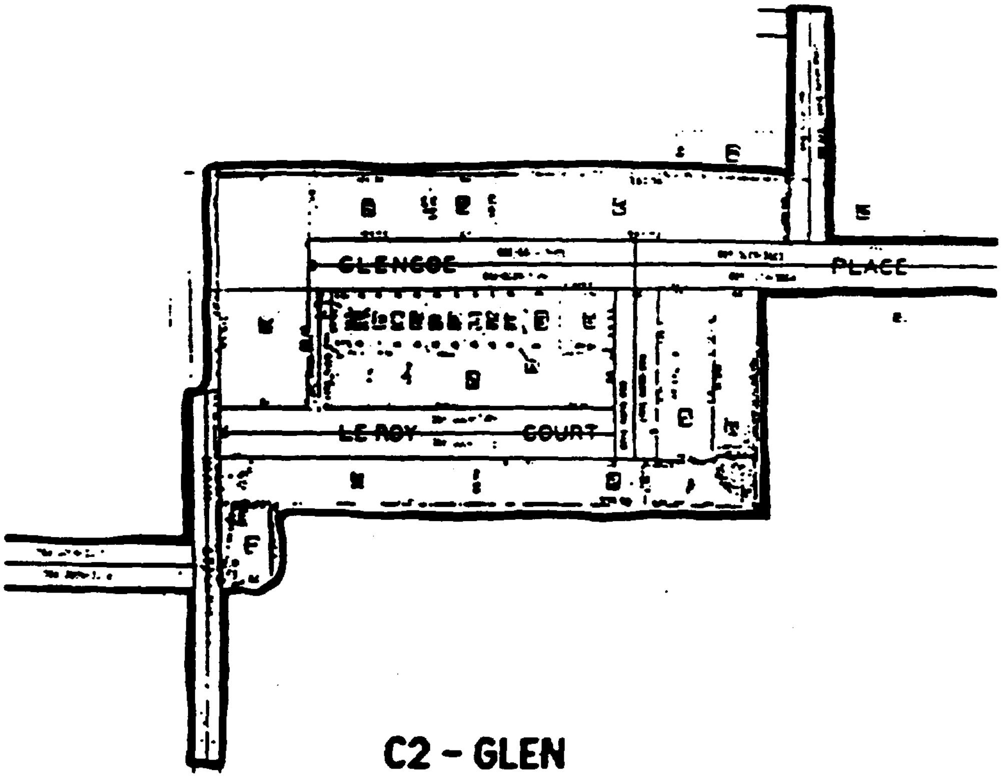


B3 - DAND

Figure 3-4. Schematic diagrams of the Back and Dandridge neighborhoods, both in Area B.



C1 - MOHA



C2 - GLEN

Figure 3-5. Schematic diagrams of the Glencoe and Mohawk neighborhoods, both in Area C.

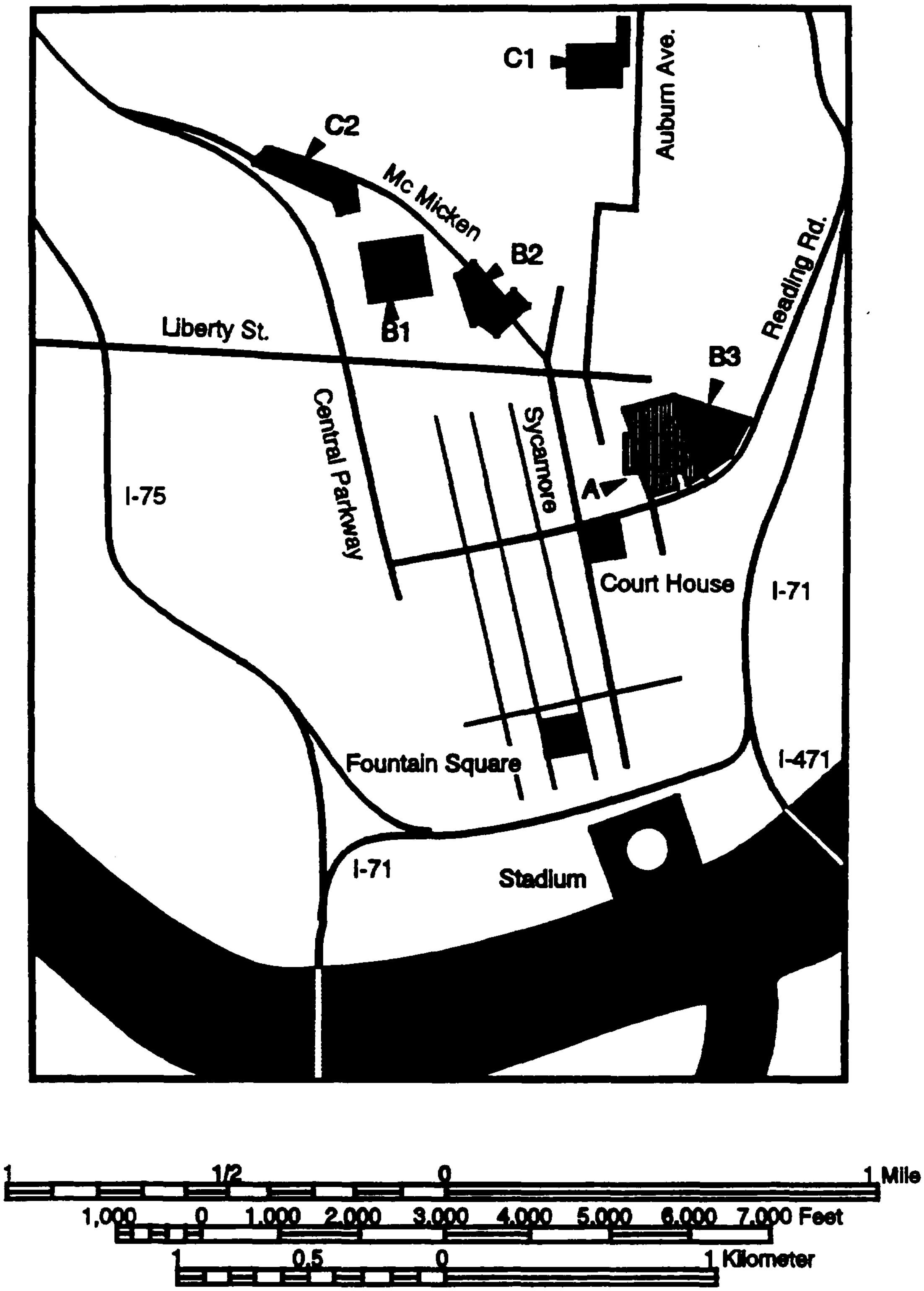


Figure 3-6. Location of study areas and individual neighborhoods in the Cincinnati Soil Lead Abatement Demonstration Project.

expense reimbursement would be provided by the project. Referral names of other potential participants were solicited.

Several days prior to the blood collection appointment, an appointment reminder was mailed and/or a reminder phone call was made to each family to encourage compliance.

A second census and enrollment period was conducted in 1990 using the same procedures as above. The first blood collection for these individuals was in Phase 05 (June-July 1990).

3.2.5 Community Relations

The Soil Project was announced with a city-wide, press conference conducted by the University of Cincinnati Department of Environmental Health and the City of Cincinnati Department of Health. The press conference was well attended by all media. (Videos of the television coverage were utilized in employee orientation sessions.) Subsequent announcements were made to local community leaders and property owners through small meetings, letters with an accompanying project fact sheet (Appendix C), and phone calls. Initial contact with potential participating families was made by individual letters and fact sheets and followed up with visits to individual homes to describe, in detail, project goals and to answer any questions.

An inner-project communication form was used to alert staff to family questions or concerns. Use of this communication mechanism allowed for greater staff/family rapport and enhanced continued family participation.

Location of the field office within the study area provided the families with convenient access to project staff. Staff remained visible and available in the study neighborhoods as well.

Prior to each abatement phase, letters were sent to community leaders and property owners describing the abatement procedures that would be implemented and alerting them of a potential community disruption that might occur as a result of the abatement (temporary playground closure etc.). Personal visits were made to property owners or tenants if appropriate.

Interaction with health and public works agencies was maintained throughout the project. Blood lead results were provided with subject consent to physicians and/or health care facilities to eliminate duplication of blood lead testing; i.e., blood lead screening efforts by the Cincinnati Health Department clinics. Further, close communication with the Cincinnati Lead Screening Program was maintained throughout the project, alerting them to children requiring more aggressive follow-up as indicated by Centers for Disease Control (CDC) guidelines. Project staff provided assistance to the Health Department in the tracking of study participants with elevated blood lead.

Project presentations were made to several interested community groups describing project plans and goals as well as providing general lead poisoning prevention information to the community.

Quarterly newsletters were sent to participating families to keep them informed of project activities and timelines. These newsletters also included general community information and activities as well as other timely articles (see Appendix D).

With few exceptions, the soil-lead demonstration project was well accepted by the study neighborhoods.

3.2.6 Subject Retention Plan

Several techniques were employed to maximize continued family participation. Caring and attentive staff were key factors in continued family participation. Because of the intrusive nature of the project, families often needed encouragement by project staff to keep blood collection, interior sample collection and interior abatement appointments.

Continual family communication was maintained throughout the project. Special family events were recognized such as family birthdays, new births and special holidays. Quarterly newsletters were sent to individual families and caregivers were encouraged to contribute articles or favorite recipes to the newsletter. Caregivers were encouraged to share photos for the "Kids Photo" door at the project office. Periodic phone calls and home visits were made to the caregivers simply to provide individual attention to the family.

To ensure families would not incur any expense associated with project participation, a fixed transportation reimbursement ($10) was provided each time a family came to the project office for blood collection. Also at the five blood collection times, each child received a modest gift. Sunglasses were a favorite choice.

Family mobility posed the greatest retention challenge. Often times, by moving, families were able to improve their standard of living. Moving meant further project participation was not possible based on project study design. Families moving during the course of the study accounted for most (98%) of the attrition. Three families were dropped from the study for repeated failure to keep scheduled appointments.

The new carpets and furniture provided as part of the interior dust abatement also served as an incentive to remain in the study for the control group (C). However, since these new furnishings were distributed to families in Areas A and B early in the study (August-September 1989) their value as an incentive in these two areas was primarily as an incentive to *join* the study.

3.2.7 Human Subject Research Review Process

The University of Cincinnati and federal and state statutes require that all research projects involving humans be prospectively reviewed and approved by the Internal Review Board (IRB). The IRB's role in human research is to protect the rights of research participants; approve research protocols that do not pose undue risk to subjects; ensure subject understanding of the nature of the research and finally, ensure that the subjects's participation was voluntary (consent form signature).

Therefore in early 1989, a detailed research protocol and consent statement was submitted to the University of Cincinnati IRB for review. Approval to conduct this human research project was obtained prior to the recruitment of participants in May 1989.

Subsequently, annual progress reports have been submitted to the IRB as required. Copies of the approved consent, medical release of information and withdrawal forms are included in Appendix E.

3.3 ABATEMENT PROCEDURES

The effects of three lead abatement strategies: soil abatement, exterior dust abatement, and interior dust abatement, were investigated as part of the Cincinnati Soil Project (CSP). At the beginning of the project in 1988, there was limited technical information available on the conduct of such abatements. Then, as now, the only cost-effective method for the abatement of lead-contaminated soil was removal and replacement. Consequently, that was the method selected.

Very little reliable data was available on the effectiveness of exterior and interior dust abatement procedures in use at that time. This lack of information required a significant effort to be expended on the development of effective protocols suitable to achieve the desired reduction in lead exposure. The abatement procedures to be used also had to be compatible with the specific requirements of a research project. Developing the interior and exterior abatement methods was the first major focus of abatement-related activities at the beginning of the Cincinnati Soil Project.

The second major focus of activities was the development of procedures necessary to perform the abatement work through the University of Cincinnati, a state institution. Certain difficulties were anticipated because some of the abatements were significant, invasive procedures performed on both private and public properties in an urban environment. The problem was compounded even further by the fact that the majority of the study population was expected to reside in rental property. Thus it would be necessary to solicit participation from families living in the rental units and additionally solicit the cooperation of the owners of that rental property. This also compounded the liabilities associated with the abatement. The University of Cincinnati would be responsible for damage both to the real property of the landlords and the personal property of the renters, the participants in the research project. Since the abatement was to take place in an urban environment other liabilities included health and safety issues associated with handling lead-contaminated materials in populated areas and operating heavy construction equipment in the same environment. Additional concerns resulted from the uniqueness of the project. It was very unusual for a public institution to make significant improvements such as the reduction of lead, on private property.

It is necessary to define abatement as it was performed by the Cincinnati Soil Project. The overall objective of the Soil Project, as stated elsewhere in this report, was to determine if reducing exposure to soil lead, exterior dust lead, and interior dust lead would result in a reduction in blood lead and/or hand lead in young children. Since there was no legal requirement to perform the abatement, all participation by families and property owners was voluntary. This resulted in some restrictions to performing a complete lead abatement.

Additionally, budget constraints also prevented total abatement of the lead in the neighborhoods where the research took place. Because of these constraints all of the environmental lead was not completely abated, exposure to lead was only reduced. The official name of the project suggests that it was not an abatement project. The Cincinnati Soil/Lead Abatement Demonstration Project was in fact an abatement demonstration project not an abatement project. That concept helped guide some decisions made during the planning and execution of the project.

3.3.1 Interior Dust Abatement Methods Development

Lead dust exists in residential buildings in a variety of locations. Lead can be found in the dust on floors and carpets. It can be distributed in the heating, ventilation, and air conditioning (HEPA) system, attics, basements, furniture, and closets. In 1989, the distribution of lead in residential units was investigated in an interior dust abatement project in the South Riverdale neighborhood in Toronto, Canada where a secondary lead smelter was the major source of the contamination. A pilot project (involving eight houses) was conducted prior to the abatement of lead which occurred in over 800 homes. The lead removed from the eight houses was distributed in the following manner:

Floors (dry removal)	42%
Surfaces (wet removal)	8%
Furnace Ducts	30%
Other Sources (dry removal)	16%
Other Sources (wet removal)	4%

The majority of the housing in the Cincinnati Soil Project was expected to utilize either steam or hot water heating systems, thus there would be no heating (furnace) ducts. Based upon this information and the overall goals and limitations of the Soil Project, an early decision was made to concentrate the abatement activities on the floor dust and that dust which accumulates on ledges, window sills and window wells. Interior methods development focused on determining effective and efficient methods for reducing dust on the surfaces. Because the floors in rehabilitated housing in urban Cincinnati were expected to be wood, vinyl, or carpet, an effort was made to develop an efficient and effective procedure to abate lead dust on wood and vinyl floors and carpet.

3.3.1.1 Development of Abatement Methods for Wood and Vinyl Floors

In order to test the effectiveness of proposed floor cleaning procedures, homes with high levels of lead in the dust were needed. Such homes were located through other research projects being carried out by the Principal Investigators of the Soil Project and other investigators within the Department of Environmental Health. These projects involved studying the effects of lead exposure in young children. The records from these projects included data on both lead levels in the interior dust and data on floor type. From those records it was possible to obtain a list of individuals meeting the following criteria:

(1) currently or recently active in other lead research projects;

(2) high lead concentrations in the interior dust;

(3) either carpet, vinyl, or wood flooring or a combination of those flooring types.

Because of these subjects' positive associations with University of Cincinnati researchers in the past, it was generally easy to obtain permission from those study participants to test cleaning methods on different wood and vinyl floors.

The questions to be answered in these homes were:

(1) In order to reduce dust lead to an acceptable level with a high efficiency particle accumulation (HEPA)-equipped vacuum cleaner, what rate of speed should the operator use and how many times should the floor be vacuumed?

(2) Would wet washing remove additional lead?

The testing procedure was as follows:

(1) Three separate squares, one meter by one meter, were delineated on the surface of the floor type being tested.

(2) A separate dust sample was collected using the dust vacuum method (DVM) (for a description of the DVM see Interior Dust Collection in the Mid-Term Project Update) from a 25 × 25 cm area from within each of the one meter squares.

(3) A bag for a HEPA-equipped vacuum cleaner was tare-weighed and installed. (In this study a Nilfisk GS80 was used.)

(4) The three squares were then vacuumed with the Nilfisk at the rate of 60 seconds for each square meter.

(5) The vacuum bag was removed and weighed after this cleaning.

(6) A second DVM sample was collected from each of the three squares and the squares were cleaned again with the vacuum cleaner.

(7) The process was repeated until the squares were cleaned a total of five times and sampled a total of six times.

(8) Each of the squares was then washed with 1,500 ml of tap water from the residence. The washing was performed by a technician using a new sponge and wearing rubber gloves. An aliquot of 500 ml was taken from each of the wash buckets. A 500 ml sample of clean water from a wash bucket was also collected to provide data on background lead levels in the tap water.

(9) A final DVM sample was collected from each square.

All of the dust samples and water samples were analyzed for lead concentration. The final result of this series of tests indicated that the lead concentration in the dust dropped from an average of 1,121 ppm to below detection and the loading dropped from 178 mg/m^2 to below detection after the first vacuuming.

3.3.1.2 Development of Abatement Methods for Cleaning Carpeting

To determine the feasibility of cleaning carpets with a vacuum cleaner, three questions were asked:

(1) Is there a difference among industrial type, HEPA-equipped vacuum cleaners in their ability to remove lead dust from carpeting?

(2) How many passes at a specified speed with an industrial-type, HEPA-equipped, vacuum cleaner will reduce the surface lead dust to an acceptable level?

(3) Is wet carpet cleaning alone or in combination with dry vacuuming effective in reducing surface lead dust?

In order to test the effectiveness of various industrial-type vacuum cleaners, manufacturers were asked how vacuums differed. Vacuum cleaners are rated differently based upon two characteristics:

(1) cubic feet per minute (cfm) of air moved by the machine;

(2) the ability of the machine to lift a column of water a specified number of inches.

Higher cfm of air moved and higher water lift were said to result in better performance. Were these differences significant? Three different vacuum cleaners which varied in these two characteristics were selected for testing (Table 3-1).

TABLE 3-1. COMPARISON OF HIGH EFFICIENCY PARTICLE ACCUMULATION VACUUM CLEANERS

	CFM	Waterlift
1) Nilfisk GS80	87	75"
2) Wap 767	100	90"
3) Euroclean UZ930	77	85"

In order to test these cleaners, it was decided to use the ASTM F607-86 *Standard Laboratory Method for Evaluation of Dirt Removal Effectiveness of Household Vacuum Cleaners*. This test procedure specifies "seeding" carpeting with known quantities of sand and talc, embedding the material into the carpet, vacuuming the carpeting, and measuring the amount of material recovered. Analysis of the data resulting from testing the three machines listed above indicated the following:

(1) There was no significant difference between operators.

(2) There was a significant difference between vacuums.

In order to determine the number of passes required to reduce the surface lead dust available to children, lead-contaminated carpets were needed. That need was again met by families who were participating in other lead-related research projects. Families living in high-lead environments, with carpets were contacted and asked if they would like to exchange their existing carpet for new carpet. Those who agreed, all of those asked, were offered a choice of carpets from three specified types and colors that a local vendor had in stock. After the selection was made, the new carpet was ordered with edges bound.

The exchange was scheduled with the participant. A crew of three performed the exchange which began with the collection of dust samples (dust vacuum method) from the old carpet and the new carpet. A sheet of 6 mil Polyethylene was placed over the old carpet for the purpose of not contaminating the top of the carpet with dirt or dust from the floor or bottom of the carpet. Enough plastic was left at the edges and the ends to seal the carpet in the polyethylene in order to prevent contamination of workers, transport vehicles and the laboratory where the research would take place. After the carpet was removed, the floor was vacuumed with HEPA-equipped vacuum sweeper and the dust was saved for later analysis. The new carpet was unrolled and the furniture was put back in place. Photo and time records were made of the process for use in the development of specifications for the abatement contractors.

The lead-contaminated carpets were then taken to a research laboratory at the University of Cincinnati where graduate students vacuumed one-meter square areas at fixed rates of speed. Dust samples were taken between each vacuum treatment. These tests indicated that even after ten passes at the rate of one minute per square meter with a HEPA-equipped vacuum cleaner (Nilfisk GS80), significant surface lead dust remained.

In order to test the effectiveness of wet cleaning, a Rug Doctor steam cleaner manufactured by the Rug Doctor Co. of Fresno, California was used to perform a series of tests in which carpets were first dry vacuumed and then steamed cleaned. Additional tests in which carpets were steam cleaned and then dry vacuumed were also performed. The results indicated that neither sequence was adequate to remove surface lead dust to an acceptable level.

The final conclusion reached from this series of tests on carpets suggested that it is more economically feasible to replace carpet than to clean carpet.

Earlier data from other investigations carried out within the Department of Environmental Health have demonstrated that just as it is difficult to remove lead from carpet, it is also difficult to remove lead from upholstered furniture. Because of this, and because of our recent data on carpets, it was decided not to do any further research on the removal of lead from furniture.

3.3.1.3 Interior Dust Abatement Procedure Summary

Interior dust abatement followed the completion of exterior dust abatement in an area if both occurred during the same time period. Interior dust abatement consisted of a combination of vacuuming with a HEPA equipped vacuum and wet cleaning non-carpeted surfaces (including window sills and wells) with a detergent. The vacuuming of floors was performed two times, each at a rate of one minute per square yard, followed by damp mopping with a detergent solution; carpets were vacuumed a total of three times at a rate of one minute per square yard each time.

Selected carpets and upholstered furniture were also replaced. Residents with one child in the study were provided with replacement carpeting for one common room, for example the living room, plus the child's bedroom. Residents with two or more children in the study received an additional carpet for a total of three carpets. Residents with a child in the study were also eligible for the replacement of one standard sofa and one standard chair.

Interior dust abatement procedures were selected after extensive methods development which revealed that chronically-contaminated carpets were not able to be effectively cleaned even after numerous vacuuming effort with a HEPA-equipped cleaner. More details on the interior cleanup methods development are presented in a manuscript in Appendix F.

3.3.2 Exterior Dust Methods Development

Lead-containing dust exists in the exterior environment on a variety of surfaces. The most common of these surfaces are streets, alleys, sidewalks, parking lots, steps and porches. The largest surface areas which were to be cleaned as part of the abatement, were the streets, alleys, and parking lots. Street cleaners would be the obvious equipment for use in cleaning these large areas. Small walk-behind units or vacuum cleaners appeared to be the most efficient equipment for sidewalks and other small areas.

3.3.2.1 Types of Pavement Cleaners Available

The first step in determining the most efficient street cleaners available for abatement of exterior dust was to determine the scope of available equipment. An initial survey of all street cleaner manufacturers marketing products in the United States indicated four different types of equipment. The four types differ in the particular mechanism used to remove dust and debris from paved surfaces. These mechanisms are as follows:

(1) Broom sweepers

(2) Vacuum-assisted broom sweepers

(3) Vacuum sweepers

(4) Regenerative air machines

The broom-type sweeper operates by one or more rotating brushes which move the dirt and debris from the pavement to a conveyor, which then carries the material to a hopper. This represents the first generation of mechanical street sweepers and has been used to clean city streets for decades. These sweepers generally use water spray to control dust.

Vacuum-assisted broom sweepers represent a further advancement of this concept. These machines operate by means of one or more rotating brushes which loosen dirt and debris from pavements and move it toward a hopper. At this point the process is assisted by means of moving air or a vacuum which pulls the dirt and debris into the hopper. These machines sometimes use water spray to help control dust. The air is filtered by a variety of filter types, some of which are effective in removing particles as small as 2-3 microns.

Vacuum sweepers operate principally by means of an extremely powerful vacuum system. Some of these cleaners will also use a rotating brush to move debris and dust from the curb to the head of the vacuum apparatus. In order to control dust generated by the rotating curb brooms, a fine water spray is often used. The exhaust air from the vacuum system can be filtered through a wide range of filter size. Most manufacturers provide a final filtration range between 2-8 microns.

The final type of pavement cleaner is the regenerative air machine. This machine operates by means of recirculating air system. The blower part of system directs a blast of air onto the paved surface, and the vacuum part of the system pulls the same air back up into the hopper. The blast of air loosens material on the paved surface and the vacuum pulls that material back into the hopper. No filtration system is needed for this machine because the air is recirculated through the system. Brushes are available to move material from curb areas into the path of recirculating air system.

3.3.2.2 Exterior Dust Testing

Because of the large number of manufacturers and the variety of machines made by each manufacturer, it became apparent that we would not be able to test all of the machines. It was decided to test the different classes of machines. Because of the lack of dust-control system on the broom-type sweepers, this class of machines was eliminated from consideration. It was also readily apparent from observing the operation of these machines and reviewing the literature that significant quantities of dust and dirt remain on the surfaces cleaned by these machines.

The types of equipment to be tested were vacuum sweepers, vacuum-assisted broom sweepers, and regenerative air machines. In order to see if one class of machines cleaned better or more efficiently than others, several different machines within each sweeper type were selected for evaluation.

Each test of a particular machine required 2 to 3 people and 3 to 4 h of time. The test consisted of finding a "worst-case" section of pavement, i.e., a section of pavement outside of the designated potential study areas, but similar to the worst kind of pavement within the study areas. The "worst-case" was thought to be the brick-paved alleyways. By testing the machines on these surfaces it would be possible to determine any differences that exist among the machines.

The test consisted of delineating four 1-meter square areas in a row on the designated pavement surface. The 1-meter squares were divided into four quadrants, designated A,B,C, and D. Quadrants marked "A" were then cleaned by scraping and vacuumed with a small portable vacuum cleaner in order to determine the original loading of dust on the surface. The material removed from each "A" quadrant was weighed. The street cleaner being tested was then driven across the four test squares. The quadrants marked "A" were recleaned with our sampling vacuum and any dirt removed from those quadrants was weighed to determining the amount of dirt/debris redistributed during the street cleaning process. The four quadrants marked "B" were cleaned by the portable vacuum sampler and the dirt/debris was weighed to determine, by subtracting from the amounts originally on "A", the amount of material picked up by one pass or the street sweeper. The sweeper was then driven across the four squares for a second time. After this vacuuming quadrants marked "A" were brushed and cleaned with our small sampling vacuums and the material was weighed again to determine any redistribution of material. The quadrants marked "B" were then cleaned, and the material weighed as before, and finally the quadrants marked "C" were cleaned, and material was weighed as before.

This test was repeated three times on one machine from each class of street sweepers. Two or three machines from each class were tested at least one time with this described method.

Analysis of the data collected from these tests indicated that several machines operated at a level of efficiency so that 98% of the dirt was removed from the surface after two passes. Selection of street sweeping equipment suitable for exterior dust abatement was based upon the results of this testing. Any machine capable of removing above 95% of the dust loading after two passes would be acceptable for the abatement work.

The results of the exterior methods development efforts are presented in an appendix.

Similar tests were carried out on walk-behind type pavement sweepers and industrial type vacuum cleaners in order to determine the most effective machine available for cleaning smaller paved surfaces.

3.3.2.3 Exterior Dust Abatement Summary

Exterior dust abatement occurred immediately after soil abatement was completed in a particular area. Streets were generally abated one side at a time, principally because of the requirement that the street be free of parked cars for complete abatement to occur. The study areas generally have more on-street parking than off-street parking and it was not practical to restrict parking on both sides of a street at any given time. Therefore, abatement occurred one side per day with the alternate side abated the following day. The paved surfaces were cleaned with vacuum equipment capable of removing greater than 99% of the dust after two passes as determined under test conditions. In some situations, hand tools were needed to loosen material in cracks and crevices prior to vacuuming, particularly along alleys and on sidewalks.

3.3.3 Soil Abatement Methods

At the beginning of the Soil Project, the soil abatement was expected to be accomplished in one of three ways depending upon the concentration of lead in the soil column (Figure 3-7). Some soil required resodding or, in some cases, the addition of topsoil to a site or part of a site prior to resodding. The purpose of the topsoil was to provide a base for the sod and/or to fill in the depressed areas, so that proper drainage could occur.

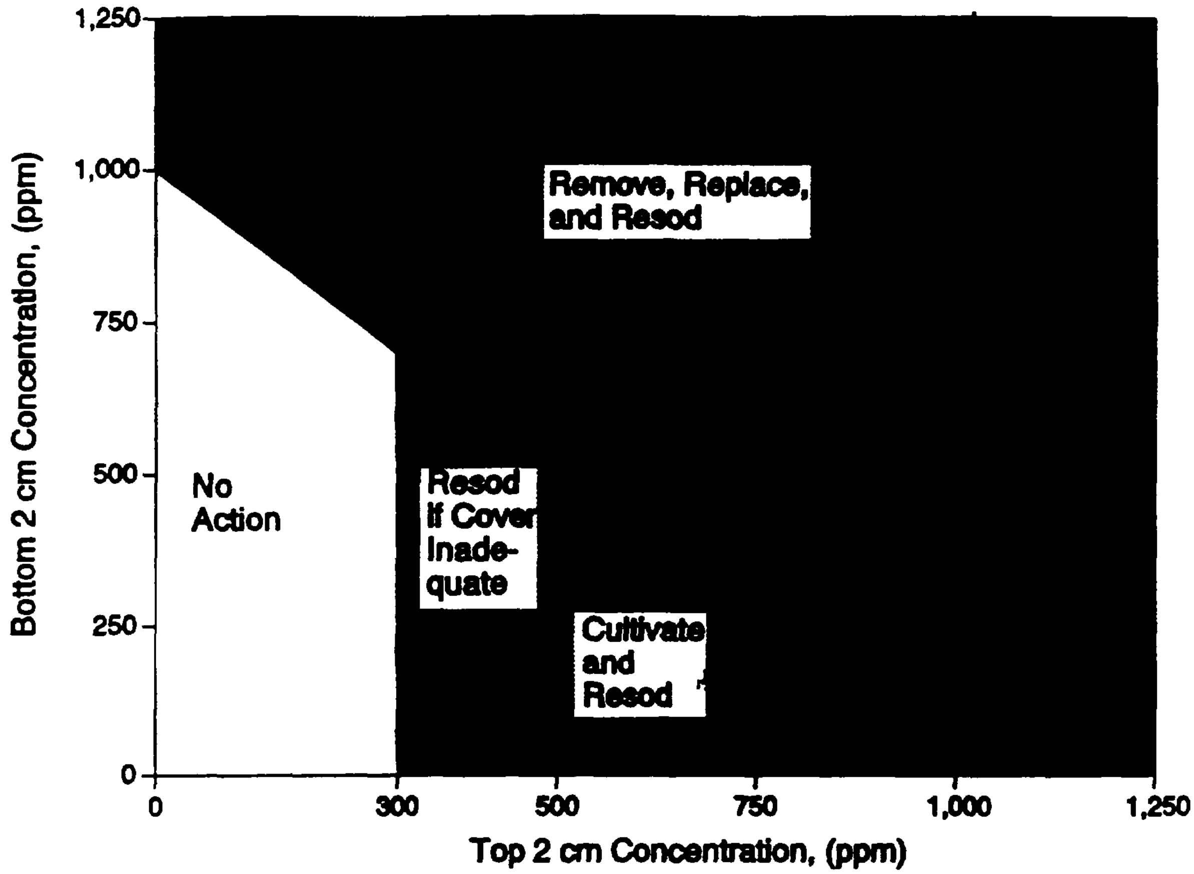


Figure 3-7. Decision criteria for soil abatement. The original plan for soil parcels with the top 2 cm between 500 and 1,000 $\mu g/g$ and the bottom 2 cm between 0 and 500 $\mu g/g$ was to cultivate and resod. Because a satisfactory method for cultivating was not available, this soil was removed and replaced instead.

On some sites tilling was attempted as the appropriate method of abatement. Preliminary testing suggested that mixing was not thorough, and delays in testing the adequacy of mixing made the procedure impractical as we implemented it. A more thorough evaluation of this method is needed. We elected to discontinue this method on this project and to remove and replace the soil instead.

On those sites where the concentration of lead required the removal of soil, the soil was excavated to a depth of six (6) plus inches and replaced with topsoil having a lead concentration of less than 50 parts per million (ppm). Where excavation was required the soil was removed by mechanical equipment either front-end loader or backhoes or hand tools. It was loaded into hoppers or dump trucks and transported to an appropriate dump site. During transport, hoppers or dump trucks were covered with tarps. Prior to loading of hoppers or dump trucks, 2 ml-thick polyethylene was placed in the hoppers of dump trucks to prevent soil from being spilled through cracks in the tailgate or beds of the transport vehicles. In order to ensure that the soil was transported to the appropriate dump site, all trucks were logged off of the abatement site by the Site Inspectors and logged into the appropriate dump site by officials at the dump site. Appropriate techniques were used to prevent spills of contaminated solid at the abatement site along with techniques for the containment of dust. Excessively dry soil was moistened with water to control dust. Replacement of soil was accomplished with a different set of equipment in order to prevent contamination of replacement soil by soil or dust remaining on equipment used for excavation. A program for the watering of sod began immediately after its placement and remained in place during the summer months. Barriers were used when necessary during soil abatement in order to protect people from injuries resulting from construction equipment. Barriers were also necessary to prevent potential additional exposure to the residents in the area.

The three abatement strategies for soil differed, depending upon the concentration of lead in a 15 cm core. Those strategies were removing and replacing, followed by sodding; cultivating, followed by sodding; and resodding. If the average lead concentration in the soil in the 15 cm column was greater than 500 ppm, regardless of the adequacy of the grass cover, the soil was removed and replaced and the area resodded. If the average lead concentration in the column was less than 500 ppm but the concentration in the top 2 cm was 500 ppm or higher regardless of its grass cover, the area was cultivated, to reduce the concentration in the top 2 cm to less than 500 ppm in both the top 2 cm and in the column and resodded. For areas where grass cover was adequate and the lead concentration was less than 500 ppm in both the top 2 cm and in the column, no abatement occurred. If the soil lead concentration in the top 2 cm was 300 ppm but less than 500 ppm and the average concentration in the column was less than 500 ppm and the grass cover was inadequate the area was resodded. No soil abatement occurred in areas where the grass cover was inadequate but the concentration in the top 2 cm was less than 300 ppm and in the column the average was less than 500 ppm.

In order to assign the specified abatement strategies to the sites in the study areas, the preliminary soil lead concentrations from the initial soil survey were superimposed over the original site maps that were used for sampling. The specific lead concentrations were written on the sampling lines shown on the site maps. Since parcel boundaries were also indicated on the site maps, we were able to tell which particular parcels required abatement by each specified method. On sites where there was only one parcel it was clear what form of abatement was necessary. On sites consisting of more than one parcel we used the following criterion:

> If all soil-lead concentrations on all parcels indicated the same method of abatement, the entire site was abated in that manner.
>
> If the lead values in the soil column indicated different methods of abatement for individual parcels on a multi-parcel site, then we used the most extensive method of abatement for any parcel requiring that method of abatement. In addition, any parcels immediately adjacent to a parcel requiring the most extensive method of abatement were abated in that manner. For example: A site containing five parcels numbered 1, 2, 3, 4, and 5, where parcel 3 had lead values in the column requiring removal of the soil and parcels 1, 2, 4, and 5 required resodding of the area as a form of abatement, then parcels 1 and 5 would be resodded and parcels 2, 3, and 4 would have the soil removed and replaced.

3.3.4 Sequence of Abatement

The second important factor in the determination of abatement neighborhoods was the presence of lead-contaminated soil. An initial soil survey was carried to characterize the lead concentration in the soil in the potential study areas.

Abatement was carried out in a specified sequence that was integrated with the environmental monitoring in the areas where abatement occurred. The preabatement environmental monitoring was completed in an area prior to the beginning of abatement. The particular sequence of abatement was soil abatement, exterior dust abatement and finally interior abatement.

Exterior dust abatement occurred immediately after soil abatement had been completed in a particular area. This work was carried out by contractors possessing the specified equipment and expertise in cleaning large paved areas. Soil project personnel coordinated the schedule of abatement work so that areas scheduled for abatement could be posted to prohibit parking. Streets were generally be abated one side at a time, principally because of the requirement that the street be free of parked cars for complete abatement to occur. The potential study areas generally had more on-street than off-street parking and it was not practical to restrict parking on both sides of a street at any given time. We therefore required abatement on one side the first day and the alternate side the following day.

Interior abatement followed the completion of exterior abatement in an area. Interior abatement occurred after the residents were oriented by Soil Project personnel. This preparation consisted of an explanation of what would occur and at the same time, the resident was asked to select the color and texture of the carpeting that was to replace existing carpeting. Soil project staff were responsible for insuring that the carpeting and furniture was available at the time of the interior abatement. The interior abatement contractor was responsible for vacuuming the dust from all ledges including baseboards, window sills, door frames, etc. The contractor was also responsible for vacuuming all of the floors at a specified rate, removing the carpet and furniture that was replaced, and installing the new carpeting and furniture. These contractors were also monitored or inspected by the site inspectors and the Cincinnati Health Department personnel working full-time with the Cincinnati Soil Project.

Because exterior abatement frequently occurred on public property, it was necessary to coordinate our activities with other agencies and utilities who commonly do work on public areas. These agencies include the Sewer Department, Water Department, Highway Department, Cincinnati Gas and Electric Company, Cincinnati Bell Telephone Company, and private contractors who occasionally will do work on public property. In addition, we wanted to be aware of any private construction projects planned or anticipated in the abatement area. The reason for this was that we did not want to be in the middle of an abatement procedure and have that process interrupted by private or public construction crews who planned to excavate an area that was just abated or who would block access to a street which we needed for abatement.

The major part of the coordination activity was performed by personnel assigned to the Abatement Soil Project by the Cincinnati Health Department. These two individuals, a Administrative Assistant III and a Senior Sanitarian had primary responsibility for this coordination. This coordination was initiated prior to the onset of abatement. In addition to planned public works/utilities work with which we had to coordinate, there were also short-term emergencies resulting from water main or gas line breaks or emergency road repairs. These problems occur for many reasons and we had no control over their occurrence. A procedure had to be established whereby we were notified as soon as possible, so that we could alter our abatement procedures if necessary.

3.3.5 Monitoring and Supervision

Contractors performed their work under the supervision of their own superintendent, who was responsible for the day-to-day operation of the abatement work. All of the abatement was inspected by soil project personnel responsible for such inspection, i.e., Site Inspectors. The Site Inspectors had the responsibility of informing the contractors' field superintendent of the time at which abatement would begin in any area. The Site Inspector also had the authority to stop work in any given area for just cause. Abatement work could be stopped in the event of physical hazard to property or personnel or failure to perform work according to specifications. The Site Inspector was not responsible for the day-to-day supervision of the contractors' employees.

3.3.6 Contract and Specification Development

Separate contracts were necessary for the three types of abatement; soil abatement, exterior dust abatement, and interior dust abatement. The three contracts were written with some parts in common, such as bidder notices, form of proposal, bid guarantee, contract bond, and contract form. Since the University of Cincinnati is a state institution, the format of some of these sections was determined by the State of Ohio. The contracts differed mainly in the section referred to as the "specifications". Specifications for the abatement work were determined by the various abatement methods development work completed prior to contract development.

The development of the abatement contracts began with the initial writing of the contracts and specifications. As with other contracts, the abatement contracts were reviewed by personnel in the Business Office in the Department of Environmental Health, the Risk Management Office of the Medical Center, and the Legal Advisory Services of the University of Cincinnati. Revisions were made based upon the needs expressed by each of the departments reviewing the documents. Once the format of the bidding documents was approved, they were sent to the Purchasing Department of the University which has an established bidding process for work contracted by the University.

3.3.7 Bidding and Contract Letting

The selection of the abatement contractors was made through an established University of Cincinnati policy. This policy was implemented through the Purchasing Department. Some University policies may serve to eliminate some contractors because they may not be able to meet established regulation. Some of these regulations that may serve to restrict the number of contractors bidding on the abatement work are:

- Any contract over $4,000 required the payment of prevailing wages.
- Bidders were required to post a ten percent (10%) bid bond.
- The contract required the posting of a one hundred percent (100%) performance bond along with separate material and labor bonds.
- Contractors were required to conform with Ohio State Affirmative Action regulations.

An additional requirement that was imposed by the management of the Soil/Lead Project was a liquidated damages clause in the contract. This also served to limit the number of interested and qualified contractors.

Contractors who could generally meet the requirements established by the University had equal opportunity to submit the low bid and be awarded the contract. Soil Project management established some policies which had the potential to influence the final selection of the abatement contractors. We were able to construct the bidding documents such that we retained the right to reject a low bidder based upon that bidder's reputation or previous experience with the University of Cincinnati. Management was also able to influence the selection of contractors by requiring that all contractors bidding on the abatement work attend a pre-bid conference. This conference served to assure that the contractors totally understood the requirements of the project. Soil Project Management evaluated all contractors based upon previous performance on jobs performed for the University of Cincinnati, other institutions, companies, and individuals.

Because of the unavailability of acceptable low bidders, the Soil Project served as the general contractors for the soil and exterior dust abatement in 1989 and for interior dust abatement in 1991.

3.4 BLOOD COLLECTION AND ANALYSIS

3.4.1 Blood Collection

Blood samples were collected five times over the course of the study with each period falling approximately six months apart. Table 3-2 shows the begin and end dates of sampling during each phase.

TABLE 3-2. BLOOD COLLECTION SAMPLING PHASES

Phase #	# of Samples Collected*	Date Sampling Began	Date Sampling Ended
01	410	6/07/89	8/10/89
03	244	10/16/89	12/7/89
05	284	6/18/90	7/24/90
07	230	11/07/90	12/10/90
09	199	6/10/91	8/08/91

*Includes subjects, adults and siblings.

The clinic used for the collection of samples was within the field facility located in the downtown area of Cincinnati near the study area. The room for sample drawing was totally separated from any other field activities and was off limits to all those not part of the clinic staff. The total clinic operation consisted of registration, an interview obtaining demographic, housing and secondary residence information, signing of an informed consent form and then finally the collection of the blood samples.

Blood samples were collected by phlebotomist trained in the proper techniques for obtaining samples for lead analysis. They were instructed in a thorough cleaning technique of the venipuncture site and also to avoid contamination of the sample or blood collection supplies. The Centers for Disease Control assumed the responsibility for providing the pediatric Vacutainer™ tubes and the butterfly apparatus for sample collection. All supplies were randomly screened by them for lead contamination.

Blood was collected for the analysis of lead, free erythrocyte protoporphyrin (FEP), hematocrit, hemoglobin, serum iron (SFe), and total iron binding capacity (TIBC). In the event a venous sample could not be obtained a fingerstick sample was collected. Of the 1,367 blood samples obtained, 65 (5%) were fingerstick collections. For venous samples, 4 ml of blood was drawn into a 6 ml disposable syringe attached to a 23 gauge butterfly apparatus. Approximately 2 ml of blood was immediately dispensed into a potassium ethylene diamine tetracetic acid (K_3EDTA)-containing pediatric Vacutainer™ tube to be used for PbB, FEP, hematocrit and hemoglobin. The remainder of the blood was placed into a second tube that contained no anticoagulant or additives. This was used for SFe and TIBC. If a fingerstick sample was required the capillary blood obtained was used for PbB and hematocrit only.

After collection, all K_3EDTA tubes were thoroughly mixed on a Nutator™ and both tubes refrigerated. Clinic personnel made deliveries of the samples to the lab within 4 h of drawing and twice a day if needed. Once received by the lab staff, aliquots were taken for PbB analysis, hematocrits and hemoglobins performed, and the remainder of the whole blood sample refrigerated until analyzed for FEP. The clotted sample was centrifuged, the serum extracted and frozen for future SFe and TIBC analysis.

3.4.2 Analytical Procedures

Blood for lead analysis was determined by Anodic Stripping Voltammetry (ASV) on the ESA Model 3010 A Trace Metal Analyzer according to the method of Roda, et al., Clinical Chemistry, Vol. 34, 563, 1988. The method involved aliquoting 100 μl of well mixed, whole blood into a metal decomplexing agent (Metexchange Reagent). This solution was placed on a mercury coated graphite electrode whereby using controlled potentials, metals were plated, and stripped. The current generated was picked up by a recorder. The peak heights which are proportional to concentration were measured and the concentration of Pb calculated from standard curves. All samples were analyzed in duplicate.

The analysis of FEP was performed by the method of Chisolm and Brown (1975). It is a double extraction method using ethyl acetate/acetic acid and hydrochloric acid. The fluorescence intensity of a sample was measured on a fluorometer and the concentration of the sample determined from a protoporphyrin standard curve. A 20 μl aliquot of whole blood was used for the analysis.

Hematocrit or packed cell volume is the total volume of the red cell mass expressed as a percentage of the whole blood volume. It is determined by centrifugation. The Cyanmethemoglobin method is a spectrophotometric technique used for the measurement of hemoglobin in a whole blood sample. The method was calibrated against a certified standard and the absorbance of 20 μl of whole blood in a reagent measured at 540 nm.

Serum iron and TIBC were measured by a technique called controlled potential coulometry on an ESA Ferrochem II Analyzer. The current resulting from reactions at the surface of the test electrode in the instrument is proportional to the concentration of iron (Fe) in the sample. The instrument automatically calculates and displays the unknown Fe and TIBC concentration in μg/dL. For Fe, 25 μl of serum was used while 100 μl was required for TIBC.

3.4.3 Quality Assurance/Quality Control

Validation of the quality of PbB and FEP measurements was accessed in part by participation in several proficiency programs. One program sponsored by the Centers for Disease Control provides participants with three unknown bloods per month per analyte. Results were compared to the consensus values established by reference and participating laboratories. Another proficiency program that we participate in comes through the College of American Pathologists. Blood samples were sent by this group for blood lead determination on a quarterly basis.

For the Urban Soil Lead Abatement Demonstration Project, additional procedures were used to validate the quality of the PbB results. Field duplicates in the form of human blood samples drawn from the same individual were split, given two different names and submitted to the lab for the complete series of analyses. They were collected at a rate of at least 2 individuals and 4 samples per week. In addition, 4 blood samples of different concentration were supplied by the Centers for Disease Control to test for any analytical or procedural variabilities within or among the three Soil Project cities. These samples were repeatedly analyzed by each city prior to the beginning of the project. During the course of the study at least two of the four were analyzed in duplicate with each set of unknowns. Furthermore, one of the two was analyzed with its identity unknown.

Internally, the laboratory employed several additional techniques to monitor and control the accuracy and precision of its PbB determinations. Human blood samples whose lead values have been previously determined by isotope dilution mass-spectroscopy (IDMS), the definitive method for lead determination, were incorporated into the analysis of the unknowns. In these instances, IDMS bloods were analyzed by giving them a fictitious name so as to be unknown to the analyst when concentration was determined. Duplicate samples of two different IDMS determined reference bloods were also analyzed with each set of unknowns. The two levels used during the Soil Project had lead concentration of 5.3 μg/dL and 40.4 μg/dL. Control charts documenting performance over extended intervals were maintained for these samples. It should be noted the calibration of the instrument also consisted of using whole blood samples whose lead concentrations were previously determined by IDMS i.e., the instrument was calibrated with primary standards. As mentioned, precision of FEP analysis was assessed by participation in the CDC proficiency program. Assurance that the same instrument sensitivity was maintained was demonstrated by periodically running a new standard curve. Another check was made by including in each weekly run, blood samples of known porphyrin concentration.

Hematology controls supplied by Fisher Scientific Company were assayed at 6 mo intervals to monitor the accuracy and precision of hematocrit and hemoglobin concentrations. Serum Fe and TIBC determinations were evaluated by checking calibration against a commercial control. In addition, to check reproducibility and instrument drift, repeated analysis of aliquots drawn from the same human blood sample pool were analyzed over time.

Results for the QA/QC techniques discussed for all sample analyses can be found in Section 4.4.

3.5 ENVIRONMENTAL SAMPLES

3.5.1 Environmental Sample Collection

Following are brief descriptions of environmental sample collection and preparation procedures. Detailed descriptions of these methods are contained in appendices to this report. A training manual for paint and water sampling is presented in Appendix G.

3.5.1.1 Soil Sample Collection

A. Soil Sample Collection Protocol

1. Site identification
   Aerial photographs with ground verification were used to delineate the potential abatement areas and the soil sites within the abatement areas.

2. Sampling Patterns and Sample Types
   The system of book, page, and parcel used by the Hamilton County Auditor provided a working system for uniquely identifying a unit of land. In addition, because parcels of urban land are generally of regular and consistent size and shape, and large areas of soil are made up of adjacent parcels, the parcel served to delineate the boundaries of a soil sampling area.

   The four types of soil sampling patterns that have been established and the situations where they are used are as follows:

Pattern	Where Used
Line (source)*	Parcels adjacent to buildings or other painted structures
Line (area)*	Parcels removed from sources such as buildings
Targeted**	Bare areas or play areas within parcels
Small Areas	Soil areas with dimensions less than about 10 ft.

   *Line segment length not to exceed 40 ft.
   **Targeted areas and line segments may lie in the same parcel.

   Two types of soil samples were collected:

Surface Scraping:	A composite of from 5 to 10 subsamples collected along a line segment, or in a small area, or in a targeted area; scraping depth = 0.5-1.0 cm.
Core Samples:	A composite of from 5 to 10 subsamples collected along a line segment, or from a small area; top depth = 0-2 cm; bottom depth = 13-15 cm.

Soil in a parcel which was adjacent to a potential source of higher lead contamination, such as a building, received more intense sampling (line [source] pattern) than soil which was relatively isolated from potential additional sources of lead. The source pattern was believed to be the most appropriate to use in an urban area, where most soil was near building foundations or streets, or was previously built upon.

Sample line segment spacings are summarized as follows:

Line (source) Spacing:	Line 1.1 = 0.5 m from boundary. The most typical boundary is a building or a sidewalk. Line 2.1 = 10 ft. from boundary. Line 3.1 = 15-20 ft. from boundary, depending on the width of the parcel. **NOTE**: if a source exists on both sides of a parcel, the numbering of line 1.1 is arbitrary.
Line(area) Spacing:	Single line 1.1 along parcel centerline; or lines spaced about 20 ft. apart in the case of an unusually wide parcel (more than 30 ft.)

Soil areas which were too small to support a line pattern were randomly sampled, following the guidelines for the small area pattern.

Targeted samples were also taken in appropriate areas such as bare areas or near play equipment. Since the targeted samples were intended to reflect potential higher exposure of children to lead in soil, only composited surface scrapings of the soil were taken.

5. Soil Sample Preparation

Samples were air dried for a period of at least five days.

Each sample was sieved twice; once with a number 10 sieve with a mesh size of 2 millimeters, followed by a number 60 sieve with a mesh size of 250 microns. Soil passing through the number 10 sieve was called the "total sample". The soil passing through the number 60 sieve was called the "urban sample". (Most of the analyses are performed on the "urban" sample.)

3.5.1.2 Exterior Dust Collection

A. Exterior Dust Sample Collection Protocol

1. Collection Apparatus

The exterior dust samples were collected on paved areas with a battery-operated portable vacuum of the type used to vacuum automobiles.

A minimum of three sub-samples of dust from 0.5 ft. × 2 ft. areas made up a single composite exterior dust sample.

Three exterior dust sampling strategies were used.

a. Neighborhood-wide sampling of abatement area

Composite samples were taken along designated blocks which did not exceed 500 ft. A template area was sampled no less than every 100 ft. along this length. For smaller areas, no less than four template areas made up the composite.

Two areas were sampled which were defined as follows:

(1) Street gutter: the interface of the street surface and the curb.

(2) Sidewalk: the edge of the sidewalk farthest from the street; or alternately, when a building abutts the sidewalk, the interface of the sidewalk surface and the building.

Since streets and sidewalks were not assigned parcel numbers on the Hamilton County Auditor's plat maps, an extension of the book, page and parcel system were used to assign a numerical identifier to the streets, sidewalks, and alleys to be sampled.

Alleys were also sampled. For sampling and "parcel" designation purposes, the alley were treated as if it was one side of the street; one composite sample from the street gutter on both sides of the alley were collected, as well as a single composite sample from each sidewalk or similar area if it exists along each side of the alley.

In addition to sampling within the abatement area, the same type of sampling was done in an approximately 200 ft. "buffer zone" which surrounded the abatement area. [This "buffer zone" also received exterior dust abatement of streets, sidewalks, and alleys and was therefore sampled to determine abatement effectiveness and recontamination rates.]

b. Partially or completely paved parcel sampling.

Exterior surface dust was collected from paved areas within soil parcels such as paved walkways. Exterior dust was also collected from completely paved parcels such as parking lots. A composite sample of at least four subsamples were collected from an area consisting of 4,000 to 8,000 square feet.

c. Samples targeted to subject residences

Exterior dust samples were collected around the building where study subjects reside. Two samples were collected around each building. One sample was a composite of no less than two template areas from the sidewalk area adjacent to the main entry of the building. The second sample was a composite of areas from the other three sides, if paved.

Exterior dust sample preparation was similar to that for soil.

If a sample was larger than 200 grams, it was split to reduce the size to approximately 100-200 grams. The following guidelines were followed in splitting samples.

1. Samples weighing between 200-400 grams were split one time.
2. Samples between 400-800 grams were split two times.
3. Samples between 800-1600 grams were split three times.

3.5.1.3 Interior Dust Collection

A. Surface Dust Collection Protocol

1. Collection Apparatus for Vacuum Method

The apparatus used to collect surface dust was a personal air monitoring pump, an air monitoring cassette containing a 37 mm diameter 0.8 micron polycellulose acetate filter, and a collection attachment.

Interior dust was sampled from areas such as the floor adjacent to the entry; from carpeted or bare floors; from window sills and window wells.

A sample of dust was collected over a measured area, or composite of measured areas so that three measures were obtained:

Dust Loading = mg dust/m^2
Lead Loading = μg lead/m^2
Lead Concentration = μg lead/g dust or ppm lead.

2. Sample Areas

Entry (E): A floor area inside the residence directly adjacent to the main entry to the residence.

Floor (F): A composite sample of at least 3 floor areas which includes but is not limited to a sample from a high-traffic area in the main living area and a sample from the child's bedroom.

If carpet was present in the residence it was the first choice of sample area. If carpet was not present, a mixture of non-carpet floor areas were sampled.

Window (W): A composite sample of at least three window areas (window sills and window wells), including but not limited to a window in the main living area and a window in the child's bedroom. The window sill was the preferred area for sampling; window wells were sampled if an adequate amount of dust was not available on the window sills.

Mat (M): The floor mat was sampled when it is put in place in the interior entry area in the home at the post blood draw environmental visit and was sampled again after the year's abatement activities are completed. At this time it was replaced and sampled at each subsequent environmental visit occurring over the next year.

B. Dustfall Collection Protocol

Dustfall samples were collected in polypropylene containers which had snap on lids. The containers had the dimensions 10 1/8 in. × 9 3/4 in. × 2 1/2 in. deep. They were "Tupperware"-type containers.

The dustfall containers were placed in the residence at the time of preabatement visits in 1989 and 1990. In practice, it was best to place the container above floor level in a relatively inconspicuous spot so that no one interfered with it. The first choice for placing the container was placed on top of the refrigerator in the kitchen. If this was objected to by the family, a nearby location was found.

3.5.1.4 Handwipe Sample Collection

A. Sample Collection Protocol for Handwipes

Collection of the hand-lead samples were done at the conclusion of each visit to a residence.

The person collecting the hand-lead samples wore disposable gloves. The person collecting the hand-lead samples cleaned his/her own hands with a disposable wipe from a separate container of wipes kept for this purpose before touching the gloves or other equipment. Once the gloves had been put on they were also cleaned well by using additional clean wipes. For each residence, where one or more child's hands was sampled, a field blank was taken. This was done in the following manner. Six wipes were removed from the container, handled to simulate wiping a child's hands and then placed in a single bag and submitted for analysis.

Lead in dust on children's hands was sampled by wiping each hand of the child with three separate commercial Wet-Wipes. All surfaces of the hand, front and back, up to the wrists, were wiped thoroughly with each of the three wipes. The wipes from each child were composited in a single sealable bag for transport to the laboratory. The total quantity of lead was reported in μg lead/pair of hands.

3.5.1.5 Water Sample Collection

Two 125 ml water samples were collected from each family participating in the Cincinnati Soil Project. Those were the W-1 sample which was a 30-min stagnation sample and W-2 which was an overnight stagnation sample. Stagnation samples were collected in order to provide some uniformity of samples and to determine the amount of lead which was dissolved in the water over a fixed time period. Collection of the water samples occurred during Phases 4 and 8 in the springs of 1990 and 1991, respectively.

The 30-min stagnation sample was collected by the Soil Project staff of environmental monitors during visits to the residents of participating families. Lead-in-paint monitoring was also completed during this visit. At the time of the visit directions and a collection vessel for the overnight stagnation sample, W-2, were supplied to a responsible adult. The sample was picked up the following morning from the residence by environmental monitors.

3.5.1.6 Paint Collection by Portable X-ray Fluorescence

The concentration of lead in paint was determined by using an X-ray fluorescence analyzer. Two types of instruments were used, the XK-2 and the XK-3, both manufactured by Princeton Gamma-Tech, Inc. The XK-3 with a range of 0-10 mg of Pb per cm^2 was the primary instrument used. The XK-2 was a backup and also used in the event a reading on the XK-3 exceeded 10 mg/sq cm^2.

In each residence two surfaces, a painted woodwork and a painted wall in each of three rooms or areas most frequently occupied by the subject child were evaluated (e.g. child's bedroom, kitchen, living room). One reading was taken at three different locations on each type of surface.

A wall and/or trim immediately exterior to the dwelling unit entry was also sampled. The sample paint sites on the exterior of a building was only examined with the owner's permission.

3.5.2 Environmental Sample Analysis

3.5.2.1 Soil

Soil Analysis

Soil samples were analyzed by XRF on a Kevex Delta Analyst Energy Dispersive X-ray Spectrometer. Prior to analysis samples were air dried on a plastic plate to constant weight. Each was then sieved by first passing the sample through a 2 mm sieve (Total Soil Fraction) and after removing a portion passing the remainder through a 250 μm sieve. This sieve sample was termed the Urban Soil Fraction and is that which was analyzed by XRF.

For determination of lead, two grams of the sieved soil (Urban Soil Fraction) were placed into labeled XRF sample cups. Operating conditions for the instrument were originally set at 30 KV, 0.5 mA, 100 lifetime seconds acquisition time, and using a Mo secondary target. The analytical conditions removed escape peaks but not background and used the intensity ratio of the Pb ($L\alpha$) peak and Mo ($K\alpha$) to quantify the lead against a quadratic calibration curve. After careful examination of the method it was determined that to increase accuracy and precision it was necessary to operate at the following conditions: 30 KV, 0.5 mA, 200 lifetime seconds and the Mo target. Analytical conditions removed escape peaks and background and now would use the $L\beta$ Pb peak instead of $L\alpha$. This was ratioed against Mo Compton-Raleigh peak. Calibration no longer used one quadratic formula, but through statistical evaluation of significance of standard curves, 2 different linear equations with a break point of 4,500 ppm were used. Also, opposite to what was done previously, concentration became the independent variable and intensity ratio the dependent variable in establishing the concentration of Pb from the standard curve formulas. The change in methods occurred after Phase 00 starting with sample #4608. The lead content of all samples analyzed prior to that were recalculated using data accumulated from reanalysis of a portion of samples and controls.

Soil Quality Assurance/Quality Control

Field lab blanks and field duplicates were collected and used to evaluate the quality and precision of all aspects of soil sample handling and analysis. Field lab blanks consisted of material obtained from a sand/gravel quarry in Cincinnati. There were three types of native soils provided:

1. Lake beds clays possibly Wisconsin glacial stage, 20-25,000 years old.

2. Illinion Till, 125,000 years old.

3. Pre-glacial Fleuvial (river) sand, 150,000 years old.

Portions of these samples were bagged, so as to resemble samples collected in the field, taken out into the field, numbered to occur randomly among the unknown samples and returned to the field lab to be sieved with the unknowns. Analysis also occurred randomly with the rest of the samples.

A field duplicate was obtained within 6 mo of the original sample. These were collected for one out of every 10 unknowns. Because lots or yards around residences are not homogenous and man-made changes may occur over time, the field duplicates were actually only a rough estimate of precision and reliability of sample collection.

Four different concentration soil samples were prepared by the U.S. Environmental Protection Agency (EPA)-Environmental Monitoring Systems Laboratory (EMSL) of Las Vegas, Nevada. These samples were numbered and inserted as unknowns into the Soil Project sample stream. Thus, at the time of analysis their identity was completely unknown to the XRF lab technician. The lead concentration of these samples was established through a round robin comparison by the 3 cities involved in the Soil Projects.

Laboratory QC consisted of weekly instrument energy calibrations and the analysis of a lo and hi control to validate each run of 14 samples. Results for the soil QA/QC can be found in Section 4.4.2.

3.5.2.2 Exterior Dust

Exterior Dust Analysis

Exterior dust samples were handled, sieved and analyzed the same as the soil samples. The XRF method change (discussed above) occurred starting with exterior dust sample #2497. Detailed descriptions for collection and analysis were present in the midterm project update.

Exterior Dust Quality Assurance/Quality Control

The types of QA/QC that were applied to soil analyses were also applied to the exterior dust samples. In fact, the field blanks and EPA-EMSL Las Vegas QC samples were the same materials as used with the soil sample analyses. The lo and hi controls were also soil and also the same as used for soil analysis. See Section 4.4.3 for QA/QC results.

3.5.2.3 Interior Dust

Interior Dust Analysis

The interior dust collection method which yields small quantities of dust precluded analysis of the samples by XRF. Consequently, all interior dust samples were digested and analyzed by flame atomic absorption spectroscopy (AAS). The process began with the removal of the dust from the plastic air sampling cassette. This was accomplished by rinsing the entire inside of the cassette with distilled/deionized water into a pre-weighed, acid soaked beaker. The sample was oven-dried and the weight of the sample determined. Acid digestion occurs in 7 M nitric acid (HNO_3), the sample was filtered and after heating brought up to volume in 1 M HNO_3. Flame AAS analysis of samples was performed on a Perkin-Elmer Model 2380 instrument. Appendices I and II give a more complete description of the procedures.

Interior Dust Quality Assurance/Quality Control

Overall monitoring of interior dust procedures was evaluated by using dust samples supplied by EMSL. These samples, prepared by EMSL, consisted of a known amount of dust added to an empty sample cassette. In order to disguise these samples, 28 fictitious family, subject and residence identities were used. (These were the same identities as given the blood field duplicates.) The assignment of samples to each identity was prepared at the field office and then sent to the laboratory as having been collected from a real family residence.

One in every 25 interior dust samples was collected in duplicate. These were collected adjacent to the spot where the actual study sample were taken. Field blanks were also collected for interior dust. This involved attaching an empty sampling cassette to the pump, setting the pump on a table with the nozzle pointed up, and running the pump, collecting only air for 3 min (average amount of time required for the collection of an interior dust sample).

Quality control was a part of each phase of sample handling in the laboratory. For each set of samples a method blank was inserted at the beginning of the preparation step and a reagent blank both before preparation and digestion. A National Bureau of Standards (NBS) standard was incorporated into each days preparation of samples as well as duplicates of a reference dust control. Another NBS standard was inserted prior to digestion. Calculation of percent recoveries and duplicate analyses were also a part of the AAS procedure.

Control charts and limits were kept to evaluate weight differences in method blanks as well as changes over time in standard concentrations. Values for blanks outside the limit of the determined balance error required corrections to be made to all other weights. Samples with weights less than 2 mg were considered insufficient for analysis.

If more than three of the five QC samples were outside the established limits the entire set was considered invalid. For the Soil Project 3 sets of 24 unknowns were not acceptable according to the QC criteria. Results for interior dust QA/QC are in Section 4.4.4.

3.5.2.4 Interior Dustfall

Interior Dustfall Analysis

The analysis of the dustfall samples was the same as previously described for interior dust. The preparation of these samples, however, was different. The dust itself was collected in plastic tupper-ware like containers with lids. The first step after opening the lid was to remove any obvious foreign objects such as insects, leaves, pins, etc. The sample was then quantitatively transferred into a 250 ml pre-weighed beaker, dried and weighed. Digestion occurred using 7 M HNO_3 and analysis was performed by Atomic Absorption flame Spectroscopy.

Interior Dustfall Quality Assurance/Quality Control

The only type of field QA/QC sample that can be acquired for dustfall is a field duplicate. In our study 1 in every 25 dustfall containers placed in a home had a second one place beside it. There were no EMSL - Las Vegas controls supplied for insertion into the dustfall sample stream.

As was the case for the interior dust analysis, lab method blanks, reagent blanks, lab duplicates and controls were a part of the laboratory's standard operating procedures for dustfall. In fact, after the original extraction of the sample from the container was weighed the method proceeded exactly the same as that for interior dust. Therefore, all the QC was combined and evaluation of the analysis consistent for both the interior dust and dustfall samples. There were no dustfall daily sets that were rejected under the QC criteria..

3.5.2.5 Hand Dust

Hand Dust Analysis

Hand dust samples were comprised of a total of six wipes - collected from each hand of the child. They were placed in a plastic zip-lock bag and submitted to the laboratory with the other interior samples from the residence. There was also a field blank associated with each residence taken at the time the child samples were obtained. This sample was used to assess whether the environment or collection procedure contributed any contamination to the study samples.

For the accuracy of the handwipe Pb concentration it was important that the supplier lot number of the wipe material or "Wet-Wipes" be documented. From experience we have found that the Pb concentration may vary from lot to lot by as much as 2.5 μg of Pb per individual wipe. Not only was it important that the child's sample and field blank be taken from the same lot but also the laboratory blank and controls. Thus, wipes were purchased in case lots only, individual bottles were labeled with the lot number, bottles were supplied to the lab, and records kept so that field and lab material would correspond.

Samples were digested using 7 M HNO_3 heated on a hot plate at 120 °C for 2 h. They were filtered, brought up to volume with 1 M HNO_3 and analyzed by flame AAS. Refer to the Appendices for more detail.

Hand Dust Quality Assurance/Quality Control

Procedures instituted for the handling of the wipe material were very important to the accuracy of hand dust Pb concentration. It was critical that field monitors were aware of the significance of lot number in the evaluation of the field blank and in the determination of the analytical QC to be used for the sample. Field blanks were obtained prior to the collection of the residence's handwipe samples and consisted of removing six wipes from the container, handling them to simulate wiping a child's hands and placing them in a sample bag for submittance to the laboratory. The concentration of these samples was used to evaluate the potential for contamination in the unknowns. Field duplicates for hand Pb could not be obtained since both hands of the child are wiped and constitute the sample.

The EMSL - Las Vegas laboratory supplied handwipe QC samples to monitor overall quality of the handwipe data. They had placed six wipes in a sample bag and spiked them with a known Pb standard solution. The supplies required for these samples were provided by us and again the importance that lot numbers be considered in the preparation of the samples was communicated. In order to disguise the samples, the 28 fictitious families instituted for QC purposes were used.

Within the laboratory, lab method blanks consisted of six unused wipes from the same lot number of material as the samples, digested and analyzed in the same fashion as the unknowns. Two lab method blanks and 1 reagent blank were analyzed with every 20 unknown samples. The mean of the method lab blanks produced an average value for that day's analysis of unknown samples. That value was subtracted from each concentration to produce a corrected μg Pb;hands. Lab controls were prepared by pipetting standard lead solutions (4, 20, 40 and 100 μg Pb/mL) onto six clean wipes in a beaker. These are also from the same lot number of material as the unknowns and digested and analyzed comparably. To validate their preparation each new set of solutions prepared were analyzed. AAS duplicates and percent recoveries were also determined on final extracts. Quality assurance/quality control results are in Section 4.4.6.

3.5.2.6 Water

Water Analysis

The water samples collected in the Cincinnati Soil Project were not analyzed by us as originally proposed but by Environmental Health Testing, Inc. (EHRT) of Cincinnati. The samples presented to them were aliquots of the original 125 ml acidified water. The analytical method employed by EHRT was a direct analysis of the sample using $Mg(NO_3)_2$

and NH_4HPO_4 as matrix modifiers and on a Perkin-Elmer Graphite Furnace Atomic Absorption Spectrometer (GF-AAS) with Zeeman background correction. The instrument is described as being comprised of a microcomputer-controlled spectrometer, a graphite furnace with Zeeman magnet, a microcomputer-controlled power supply for the graphite furnace and a printer for automatic reporting of results. The injection site consisted of a paralytic coated graphite tube with L'vov platform. Only 1 ml of sample is required for preparation and 25 μl aliquots of the prepared sample injected into the furnace. Calibration is from 0-35 μg Pb/L and sample results are given in μg/L. The method detection limit is 1 μg/L.

Water Quality Assurance/Quality Control

Field blanks and field duplicates were parts of the collection procedure for water sampling. Field blanks involved taking a 125 ml bottle of distilled/deionized H_2O into the home and allowing it to sit opened on the sink during the time the comparable study sample was being collected. These were collected at 5% of the residences. Duplicates were collected at 10% of the residences and done immediately following the initial visit and sample collection at the residence.

In the laboratory distilled/deionized water samples and controls were incorporated into the samples sent to EHRT. It was specified to that lab that samples of a control should be analyzed with each set of samples. In addition, all samples were analyzed in duplicate and percent recovery determined on 100% of the samples submitted. Results are given in Section 4.4.7.

3.5.2.7 Paint

Paint Analysis

The concentration of lead in paint was determined using two types of X-ray fluorescence analyzers both manufactured by Princeton Gamma-Tech. The XK-3 instrument has a range of 0-10 mg/cm^2 and was the primary instrument used. The XK-2 model was used as a backup and because of its extended range (0-75 mg/cm^2) in the event the reading exceeded 10 mg/cm^2.

The measurement of the lead concentration in the paint is fully automatic. The instrument is placed on a designated surface and the handle depressed. Usually within

25 seconds the lead content of the paint will appear on the digital display of the instrument. However, prior to taking any concentration reading the instrument must be calibrated (XK-2) or the calibration must be checked (XK-3). This is accomplished by using various levels of lead film supplied by National Institute for Standards and Technology (NIST).

Paint Quality Assurance/Quality Control

Proper calibration and instrument operation were important factors contributing to the quality of the XRF concentration readings. The instruments were calibrated and checked using NIST lead film. These lead paint reference materials were developed by NIST for the Department of Housing and Urban Development. At each residence single paint calibration checks were made at the beginning and end of all measurements. For calibrating the XK-2, readings were taken with the zero lead standard, the 1.5 mg/cm^2 standard, and the 2.99 mg Pb/sq cm paint standard. The XK-3 was checked by using the 0.6 mg/cm^2 lead and the 2.99 mg/cm^2 standards.

To avoid errors in registering an incorrect value, the operator read the number for the other team member to record. This was then read back to the operator. Also to reduce the precision error of a residence room one reading was taken at three different locations on each of the two surface types and in each of the three rooms tested.

In addition to the XRF readings, a semi-quantitative evaluation of the condition of the painted surface was made. Using a scale of 1-3 the surface tested was rated as intact, tight paint or deteriorated. The paint condition and lead content was combined to give a weighted paint hazard score that has been shown to correlate with blood lead in children.

3.6 HEALTH AND SAFETY PLAN

A Safety and Health Plan (SHP) was written and implemented for the Cincinnati Soil Lead Abatement Demonstration Project in November 1988. The purpose of the plan was to have a written set of work procedures and safety standards to protect workers' health and safety. The plan was written by the projects Safety and Health Officer (SHO) and reviewed by a team of safety and health experts. Revisions and updates to the plan were made annually or as necessary.

Contents of the Safety and Health Plan included:

Project Description,
Site Descriptions,
Organization and Coordination,
Site Characterization,
Training,
Employee Protection,
Medical Surveillance Program,
Site Control,
Decontamination,
Emergency Response, and
Standard Operating Procedures.

A publication describing the development of Safety and Health Plan and its initial implementation appears in Appendix H.

Monitoring and controlling worker exposures to hazardous elements, including lead dust, at the worksite were priorities of the Safety and Health Officer. Worker training, medical surveillance, field and laboratory audits and personal air and sound level monitoring were methods used to limit or prevent worker exposure to environmental hazards.

3.6.1 Training

All personnel potentially exposed to hazardous materials received basic safety and health training before working with the project. All training sessions for new project employees or contractors consisted of a minimum of the following topics.

1. Rights and Responsibilities
    a. Safety and Health Plan
    b. Occupational Safety and Health Administration (OSHA) lead exposure levels
    c. Medical Surveillance Program

2. Hazard Recognition and Control
    a. Site Characterization
    b. Health Effects
    c. Radiation
    d. Hazard Communication

3. Work Practices
    a. Standard Operating Procedures
    b. Fire Prevention
    c. Equipment Use
    d. Acquired Immune Deficiency Syndrome (AIDS) Awareness

4. Personal Protective Equipment
    a. Protective Clothing
    b. Respiratory Protection
    c. Decontamination

5. Emergency Response
    a. "Buddy System"
    b. Contacting Emergency Resources
    c. First Aid

Initial and annual training was conducted by the project's Safety and Health Officer (SHO) and at times by other safety professionals. Training was in accordance with 29 Code of Federal Regulations (CFR) 1910.1200 and recommendation for personnel exposed to blood borne pathogens.

Training sessions were usually between two and 6 h in length and were modified for specific job tasks. An example of an agenda for contractor training is attached as Appendix I.

3.6.2 Medical Surveillance Program

The MSP was designed to assess and monitor workers' health and fitness before employment and during the course of work, provide mechanisms for emergency and other treatment as needed and detail methods for accurate record-keeping for future reference.

Medical surveillance was provided for all personnel who were exposed to hazardous substances or health hazards. All expenses related to medical surveillance were borne by the project. Medical surveillance included the following:

Pre-employment screening to assess the workers' health and fitness for his/her job was provided to designated employees. The employer provides the examining physician with a description of his/her job duties. The SHO provided a copy of 29 CFR 1910.120, 29 CFR 1910.1025, 29 CFR 1910.95 with appendices and other applicable OSHA standards or guidelines, occupational health clinic for use by the examining physician.

a. Occupational and medical history, particularly with regard to cardiovascular or respiratory disease; exposure to lead or blood-borne pathogens; and adverse outcomes especially neuromuscular, reproductive and gastrointestinal dysfunction; musculoskeletal disorders or impairments; and atopic diseases.

b. Comprehensive physical examination of all body organs (excluding pelvic and rectal systems)focussing on hepatic, pulmonary cardiovascular and musculoskeletal systems.

c. Baseline determinations by urinalysis, with differential, and Chem-23.

d. For personnel potentially exposed to contaminated dust or soil, baseline testing of blood lead level and zinc protoporphyrin (ZPP) (or FEP).

e. For personnel whose exposures to noise equaled or exceeded an 8-h time-weighted average of 85 decibels.

f. For personnel who wore respirators, a determination of fitness to wear a respirator was made.

g. For personnel involved with environmental monitoring, physical capacity screening evaluations were conducted to determine fitness for sample coring, if recommended by the examining physician.

h. For personnel handling blood products, determination of the baseline hepatic profile and hepatitis B antibody status is recommended; Hepatitis B vaccinations were made available, as appropriate.

i. Environmental personnel were vaccinated against tetanus, as appropriate.

Periodic medical examinations were provided to monitor workers' health and fitness during the course of work. These were compared to baseline data to determine biologic trends that may mark early signs of adverse health effects, and thereby facilitate appropriate protective measures. Included are:

a. Annual medical examinations.

b. Biologic monitoring for personnel exposed to potentially contaminated dust.

   i) Blood lead every 6 mo.
   ii) ZPP (or FEP) every 6 mo.

c. Audiometric monitoring for personnel whose exposures equaled or exceeded time-weighted average of 85 decibels.

   i) audiometric exam annually.

Medical examinations were provided as soon as possible upon notification that the worker had developed signs or symptoms indicating possible over-exposure to hazardous substances or health hazards or that an unprotected employee had been exposed in an emergency situation. Treatment was provided at the discretion of the examining physician. If the cause was determined to be occupational, the SHO was notified.

Any employee who experienced a needle stick, cut, human bite or mucous membrane exposure which created the risk of exposure to blood borne pathogens was subject to the procedures contained in a Needlestick Policy.

For personnel exposed to potentially lead-contaminated soil or dust, medical examinations were provided at termination of employment or job reassignment. Blood lead levels were assessed at the same time unless the employee had a sample(s) checked within the previous thirty days.

Medical examinations were performed by occupational medical physicians of the University of Cincinnati Occupational Health Clinic. Laboratory analysis of blood for lead was performed by accredited labs under contract with the clinic or the University of Cincinnati laboratory affiliated with this project. All other biological samples were analyzed by an accredited laboratory selected by the physician. All employee health and medical records were maintained in the Occupational Health Clinic in accordance with the requirements of 29 CFR 1910.120(f)(7). Employees received the physician's written opinion in accordance with 29 CFR 1910.120(f)(6).

Emergency and Non-Emergency Treatment

Provisions for emergency treatment and acute non-emergency treatment were made for each site.

1. Emergency first aid:

   a. Team leaders were trained in first aid by the American Red Cross.

   b. A standard first-aid kit was available in laboratories and cars used to transport worker to field sites.

   c. Eye-wash units were available in all laboratories and checked at least weekly by a designated lab tech and quarterly by the SHO or representative for adequacy of operation.

   d. Team leaders notified "911" or transported an injured or affected employee to the University Hospital if the injury required more than first-aid.

2. Record-keeping

Proper record-keeping was essential to protect worker health and safety.

a. Medical records will be maintained by the Occupational Health Clinic and preserved on exposed workers for thirty (30) years after termination of employment (29 CFR 1910.120).

b. Reports by the Occupational Health Clinic were maintained for each employee by the SHO. A copy of each report was sent to the employee upon receipt from the clinic.

c. Records of occupational injuries and illnesses were maintained and posted yearly by the SHO.

The SHO at least annually ascertained that each accident or illness was promptly investigated, evaluated the efficiency of the medical surveillance program, reviewed potential exposures and site safety plans and reviewed emergency treatment procedures.

3.6.3 Workplace Audits

Assessments of potential hazards in the work sites were conducted before work commenced in accordance with 29 CFR 1910.120(c). This assessment included a determination regarding the applicability of 29 CFR 1910.1926 (Construction Standard), 29 CFR 1910 (General Industry Standard), and other OSHA, National Institute for Occupational Safety and Health, or American Conference of Governmental Industrial Hygienists guidelines, as appropriate. It was anticipated that employees would not be exposed to airborne lead that exceed the action level defined in 29 CFR 1910.1025.

3.6.3.1 Laboratory Audits

Laboratory facilities were initially reviewed by the SHO or designate to determine potential exposures to lead or other hazards. Appropriate controls and the use of personal protective equipment were instituted as necessary.

On-site reviews of laboratories were conducted on a regular basis. Copies of the SHO's report were given to the laboratory supervisor, project managers, and administrative manager. A copy of the form used for the laboratory audits and a listing of those performed are contained in Appendix J.

3.6.3.2 Interior and Exterior Field Audits

The SHO or designate monitored field workers on a regular basis to assure compliance with guidelines as stated in the SHP. When hazards existed, the SHO or designate alerted the employee to the problem, addressed the issue with the field supervisor and recorded the findings in their report. Follow-up audits were conducted to insure the problem or safety hazard was corrected. Follow-up audits were performed within a two week period when recommendations by the SHO or designate required any safety improvements. Response to safety recommendations were implemented and enforced. As abatement commenced each season, safety concerns were discussed with supervisors and reinforced to abatement workers. The forms used for these audits and a listing of those performed are contained in Appendix J.

3.7 DATA MANAGEMENT

3.7.1 Data Management Objectives

To ensure data integrity, accuracy, and completeness.
To maintain the accountability and security of all project data sets.
To provide timely support to project day to day operation.
To provide quality data for data analysis.
To protect study family/subject confidentiality.

3.7.2 Data Management System Development

A data management system (DMS) based on Apple Mackintosh computers was developed by following these steps: users' needs survey, system analysis, system design, system programming, system implementation, installation and training, and system operation and maintenance.

3.7.3 Users' Needs Survey

We surveyed the users' needs, users computer experience and training, and their familiarity with the existing data management system. We also studied the system which had previously been used by our staff, the needs of this project as stated and the project data management objectives.

rs on a regular basis to assure compliance
ds existed, the SHO or designate alerted
vith the field supervisor and recorded the
iducted to insure the problem or safety
ormed within a two week period when
l any safety improvements. Response to
orced. As abatement commenced each
isors and reinforced to abatement
ting of those performed are contained in

eteness.
all project data sets.
y operation.

nent

pple Mackintosh computers was
vey, system analysis, system design,
tion and training, and system operation

xperience and training, and their
We also studied the system which had
roject as stated and the project data

3.7.6 Design of the Components of Data Management Engine

File Structure

Hierarchical File Structure

Files/data sets are saved within a *form* sub-directory. Form sub-directories are created within a *phase* sub-directory, where phase stands for the study phase. In this project, we have ten study *phases* and within each study phase we usually have many sample collection forms, sample chemical results forms, and questionnaire forms. Within a given form of a given phase, we have data set files, entry screen files, report files, and several other files for maintaining data integrity. These files are saved in the designated *form sub*-directory.

Coherent and Consistent File Structure

Within a *form* sub-directory, the file structure is the same, so automatic file management can be programmed. The following is a brief list of the kind of files in a *form* sub-directory.

Project's data sets for each data form are entered as the batched data sets initially and then appended as a master data set. *Data form information data* set saves the key information of this data form. *Data definition dictionary* has the field definitions, field coding and the units of all the measurement variables in a data set. Three kinds of *computer data entry screens* are programmed to provide data entry, update and retrieval. *Report generators* are used to generate reports. Each report generator has consistent layout to ensure its readability. All project data sets have the same data structure. Each project data set has three kind of fields: linkage identifiers, data fields, fields for data management. The linkage identifiers are defined at the beginning of each data set and are used to link all the records in different data sets. The collected project data are entered into the data fields after the identifiers. Several fields for data management use are assigned at the end of the project data sets.

Data Linkage System

A system of identifiers is defined by assigning an identification code to the following entities: property, building on a property, apartment in a building, family in an apartment and subject of a family. This system is the key to link all the data which were entered in different forms of different phases together for data analysis and/or report printing.

User Interface

This system has a menu driven graphic user interface. It was programmed to support both mouse and keyboard, for user's convenience. Data management subroutines, i.e., error checking and record searching, are available as menu items. It supports on-line editing and two-level data access: data editing with review or review only without editing.

Error Checking Routines

An error checking routine is programmed to compare the data which were entered by two different individuals (double data entry). Range check and data coding validation subroutines are also programmed.

Data Update Routine

An update subroutine with roll-back capability was programmed to ensure data integrity. A data set was created to record the history of all the changes of a given data entry form. Whenever an update was executed, the information before and after the update would be recorded.

3.7.7 System Programming

System Engine Programming

The strategy that we took to finish the system engine programming was: We wrote the generic routines for each function to be performed and tested them; combined the tested routines for accomplishing a defined task as a module; and finally combined all the tested modules as the data management engine. The required programming time for completing the programming of the *data management engine* was equivalent to two seasoned programmers for 9 mo. The programs to provide the form-based data entry system were written when a *form* had been developed and its data was ready for entry.

Programming for Each Form-Based Data Entry System

The programming of a form-based data entry system included the data structure creation of all needed data sets, preparation of data definition dictionary, data entry screens programming, report generator programming, etc. All of these programs and files were saved in the given form sub-directory. Thus, we can consider the form-based data entry system for each form as a peripheral: plug it into the data management engine when we need to use it.

3.7.8 System Implementation, Installation, and Training

System implementation included computer software and hardware requisition, set-up and installation, programmer training, programs compilation, and user training. The software used to develop our data management engine is FoxBase+ for Apple Mackintosh. Training was provided after the software and hardware were available or after our Data Management System (DMS) was installed. This system can be installed by a trained staff member.

Implementation for End Users

Personalized tutorial and system user's guide was available when our system was installed for a user.

3.7.9 Data Base Management Operations and Maintenance

Data base management operations included routine form-based data entry system programming, data entry and edit, data error checking and update, report printing, data merging and data clean-up, etc. Data base management maintenance included hardware maintenance, software bug fixes, and user technical supports.

3.7.10 A Summary of Project Data Base

In the Appendix, several charts were used to present the file structure, data flow and the data entry and update procedures of the Cincinnati Soil Project database. After that, a summary list of all project data sets with the number of records in each data set was given.

3.8 GEOGRAPHIC INFORMATION SYSTEM

3.8.1 What is a Geographic Information System?

A geographic information system (GIS) is a computer system which can not only integrate *geographic data* and *tabulated attribute data* together for further retrieval and analysis but also support manipulation and presentation of spatially elated data. In this project, the GIS that we used was called a generalized GIS. A generalized GIS is a GIS which supports spatial statistical data analysis and modeling in addition to the available GIS capabilities. The software used as our generalized GIS included: ARC/INFO, dBASE, SAS, BMDP, and SPSS.

3.8.2 What Did We Plan To Achieve with Our Geographic Information System?

(1) Identify the spatial distributions of environmental toxicants, e.g., lead, in the study areas. (2) Investigate the spatial relations between environmental toxicants and human exposure biomarkers. (3) Study the exposure pathways of human subjects to environmental toxicants. (4) Study the migration pathways of environmental toxicants. (5) Propose environmental remediation strategies and plans. (6) Manage and monitor the remediation. (7) Measure the effectiveness of remediation and hence evaluate different remediation procedures. (8) Study the rate of recontamination after remediation. (9) Retrieve and present study outcomes, especially as maps.

3.8.3 Application of a Geographic Information System in This Study

The geographic locations of the environmental sampling sites and buildings where study subjects lived were digitized as different GIS layers. The sample collection information and sampling results as well as subject questionnaire data were then merged to the associated GIS layers for future analysis. Thus the available data can be analyzed by their logical relations and spatial relations. For example, we had the building layers, the street layers, the soil layers and the property layers digitized for each study neighborhood and we merged the house interior dust lead results to the building layer, the soil collection information and soil lead results to the soil layer and the street dust lead concentrations to the street layer. The spatial relation between the building house interior dust lead and the soil lead (or street dust lead) could then be studied.

3.8.4 The Contribution of a Geographic Information System to This Project

A GIS was essential for the full utilization of the soil and exterior dust lead data in the Cincinnati project because of the area-wide nature of these data. Much of the soil in the study area was *not* associated with specific housing units, but was in playgrounds, vacant lots and at nearby housing units. A child therefore could have potential exposure to lead from a number of these areas. Similarly the exterior dust sampling protocol involved collecting composite dust samples from all of the streets, sidewalks, alleys, and parking lots in the study areas. The GIS provided a mechanism to determine soil and exterior dust lead concentrations within specific distances of each child's residence.

3.9 DATA ANALYSIS

3.9.1 Data Analysis Objectives

1. Test project hypotheses,
2. Evaluate the quality of project's data,
3. Quantify the correlations between environmental lead measurements and human lead biomarkers,
4. Identify the key variables which can be used to quantify the changes in human lead biomarkers,
5. Conduct not only prospective and retrospective data analysis but also a sequence of cross-sectional data analysis to understand the changes in environmental leads and human lead biomarkers,
6. Identify the spatial distributions of environmental leads in the study areas,
7. Investigate the spatial relations between environmental lead and human, exposure bio-markers,
8. Study the exposure pathways of subjects to environmental leads,
9. Study the migration pathways of environmental toxicants,
10. Measure the effectiveness of different remediation procedures,
11. Study the rate of recontamination after remediation,
12. Propose environmental remediation strategies and plans.

We accomplished these objectives by going through the following data analysis plan. Due to the complexity of the data sets, we were not able to complete all data analysis within the current available time frame.

3.9.2 Data Analysis Plan

The following were the key items in our data analysis plan:

Data conversion after completing data entry, error checking and updating;
Data clean-up and data coding-update;
Data list printing;
Preliminary data analysis: summary statistics and frequency distributions;
Correlational data analysis: correlation analysis, regression analysis (or analysis of covariance);
Confirmatory data analysis: testing project hypotheses and the effectiveness of lead abatement;
Prospective, retrospective and sequences of cross-sectional data analyses;
Modeling; and
Statistical methodology development.

3.9.3 Data Conversion

When data were entered and error checking was completed, several data conversions have to be performed to ensure that comparable and accurate data were available for data analysis. All project data were entered into Apple Mackintosh computers, through the following steps, and then transferred to the University of Cincinnati's IBM mainframe computer: First, convert project data base from Apple Mackintosh under FoxBase+/Mac to IBM PC under dBASE. Second, convert this dBASE data base to PC-SAS data base with the correct data type defined. Third, upload these PC-SAS data sets to mainframe computer.

3.9.4 Clean-Up Data and Data-Coding Update

(I) Check the linkage identifiers in each data set and make sure that all data in any single data set can be merged with the associated data set, e.g., subject questionnaire data set should be merged with blood lead data set. (II) Check the data range and data coding to ensure that the data to be analyzed were valid, e.g., outliers and missing values were checked. If any errors were found, the master data set was updated by following the established data update procedure.

3.9.5 Data List Printing

The data listing was printed after the clean-up of a data set was finished. This data listing was visually reviewed and checked after it was printed.

3.9.6 Preliminary Data Analysis

Summary statistics:

Mean, standard deviation, geometric mean, geometric standard deviation, median, percentiles, etc. were computed for each environmental sample, e.g., soil lead house-interior dust lead, exterior dust lead, etc., and human biomarker, i.e., blood lead and hand lead. These summary statistics were computed for all the data in each individual phase and the data which was collected in both preabated and postabatement phase. So, we can have a good understanding about the collected data; and the comparisons between preabatement and postabatement can be made easily.

Frequency Distributions

The frequency distributions of all the key variables were studied by the following four approaches:

1. Single Data Form Based Analysis,
2. Multiple Data Forms Within a Single Study Phase,
3. Same Data Form From Several Study Phases,
4. Multiple Data Forms From Several Study Phases.

With a good understanding of the characteristics and the distributions of all the key variables, we were able to propose more suitable statistical modeling and testing techniques to analyze our data.

3.9.7 Correlational Data Analysis

Correlation Analysis

This was to study the correlations between human lead biomarkers and different environmental lead concentrations, e.g., compute the correlations between blood lead, hand-wipe lead,house interior dust lead, exterior dust lead, etc. Study the relationships between human lead biomarkers and study subjects' mouthing behaviors as well as between human lead biomarkers and their families' social economical status. We also investigated if lead abatement had any impact on these correlations.

Regression Analysis and Analysis of Covariance

The regression analysis was used to predict the changes in human lead biomarkers from the changes in the environmental leads, e.g., house interior dust lead, exterior dust lead and soil lead. It was also be used to identify the key variables which have the significant influence on the changes of human lead biomarkers. If at least one independent variable was a categorical variable, e.g., the treatment group variable, then the regression analysis may not be suitable, but the analysis of covariance can be used to achieve the above two goals.

3.9.8 Confirmatory Data Analysis

Test the Proposed Project Hypotheses

Study the Effectiveness of Lead Abatement

Several statistical procedures have been applied to study the effectiveness of lead abatement: T-test, Analysis of Variance, Analysis of Covariance, etc. The nonparametric statistics were considered when the assumptions of the classical procedures was not appropriate.

3.9.9 Prospective, Retrospective, and Sequences of Cross-Sectional Data Analyses

To study the changes in the human lead biomarkers and the environmental leads, we propose to identify the key variances which had influences on these changes individually or collectively through prospective retrospective and sequence of cross-sectional data analysis.

3.9.10 Modeling

Modeling the Distributions of Environmental Leads

Where are the sources of environmental lead contamination? How do they spread? Or, what are the distribution patterns? skewed or symmetric, uni-modal or multi-modal. We also considered modeling the temporal distributions and spatial distributions of environmental leads.

Modeling the Rate and Pathway of Recontamination of Environmental Lead

The understanding of the rate and pathway of environmental lead recontamination after lead abatement will provide improved strategies for abating and reducing lead in the future.

Modeling Human Exposure Pathway to Environmental Lead Through Modeling the Relationships Between Human Lead Bio-markers and Environmental Leads

We were interested in identifying and quantifying which and how study subjects were exposed to environmental lead, e.g., soil lead, exterior dust lead, house interior dust lead, paint lead, water lead, etc. A human lead exposure pathway model made it possible for us to quantify the contributions of environmental leads to human lead body burden.

Establish A Model To Predict The Changes In Human Lead Biomarkers If Environmental Lead Was Abated From One Level To Another Level, i.e., to quantify the impact of abatement

We were also interested in quantifying the contributions of the environmental lead abatement to the changes in environmental lead and to the changes in human lead biomarkers.

3.9.11 Statistical Methodology Development

As mentioned before, many classical statistical procedures are not quite suitable for analyzing our data due to the complexity of this study. Several statistical procedures were investigated to provide satisfactory approaches to analyzing our data. We have some results from these investigations, but more efforts are needed.

Statistical Methods for Analyzing Familial Data

In this project, we have some study participants who came from the same families. In some situations two families occupied the same apartment unit. The consequence to this was that the needed assumption of many available statistical procedures may not be suitable. For example, the usual Pearson sample correlation was not always appropriate to estimate the "true" correlation between the blood lead and hand-wipe lead of our data, because it could be biased. There are several other cases like this. We have good progress in obtaining a "good" procedure to estimate the correlation between hand-wipe lead and blood lead with which these samples were collected from the families with varied sib sizes. However, before we have our methodology fully developed, we may have to use the not appropriate "usual" statistical procedure to understand or analyze our data.

Statistical Methods For Analyzing Spatially Related Data

Our study was a neighborhood-wide study, so our lead variables are spatially correlated. A generalized GIS system has been set up to facilitate analyzing our spatially related data and several statistical procedures were investigated. However, because the final report deadline was before a complete data analyses had occurred, we were not able to complete this analysis. We will continue the work in this area as time and resources allow.

Statistical Methods For Analyzing Longitudinal Data

To analyze the changes of lead concentrations or loadings over time, e.g., postabatement vs. preabatement, the recognized approach is using longitudinal data analysis techniques. Several methods are available and will be used in analyzing our data, e.g., structural equations with latent variables, linear models, and generalized linear models. However, due to the covariance structure of our data, these methods needed further modification to ensure that the relevant assumptions are fulfilled.

A Measurement Error Model With Random Coefficient Approach To Analyze Inter-laboratory Calibration Data

We proposed a statistical model which can fully explain why the sample variance increases as the chemical concentration increases. The statistical methodology development is still under way and we have had our preliminary results presented in a national statistical conference. Currently, we obtained some results which can tell us if the concentrations of the unknown standards from a lab is statistically the same as the *consensus* sample concentrations.

3.10 PROJECT ADMINISTRATION

3.10.1 Financial Management

A budget and expense tracking system was used to financially manage the grant for the Cincinnati Soil Lead Demonstration Project. The tracking system was developed to more effectively manage the project budget and track expenditures by cost center.

The University, like most large organizations with a central accounting department, did not provide detailed information necessary to manage an individual grant, on a timely basis. Our budget and expense tracking system provided a monthly review of performance against forecast. The reports generated on a monthly basis included:

1. Comparison of Project budget vs. expenses/encumbrances. (Year-to-date and Project-to-date)

2. Comparison of monthly budgeted payroll vs. actual expense and accumulated monthly P/R expense for reviewing trends.

3. Cost Center reports (8) with budgeted vs. actual comparison. (Year-to-date and Project-to-date)

4. Project summary report, detailed by category with budget vs. actual comparisons. (Year-to-date and Project-to-date)

5. Cost Center summaries were created for a review of total expenditures specific to each individual cost center. Such detailed and specific information may be used for decision making purposes or determining unit cost within an individual cost center.

The following information describes the order of activities involved in utilizing our budget and expense tracking system. A flow diagram (Figure 3-8) of the "Budget tracking System" is displayed on the following page.

Cincinnati Soil Project Budget and Expense Tracking System

The University of Cincinnati's financial system is called College and University Financial System (CUFS). The accounting department at the University provided two monthly reports: a budget summary report and labor distribution report. These reports included each current month's expenses and encumbrances. We usually received these reports 2 to 3 mo following the closing of the month.

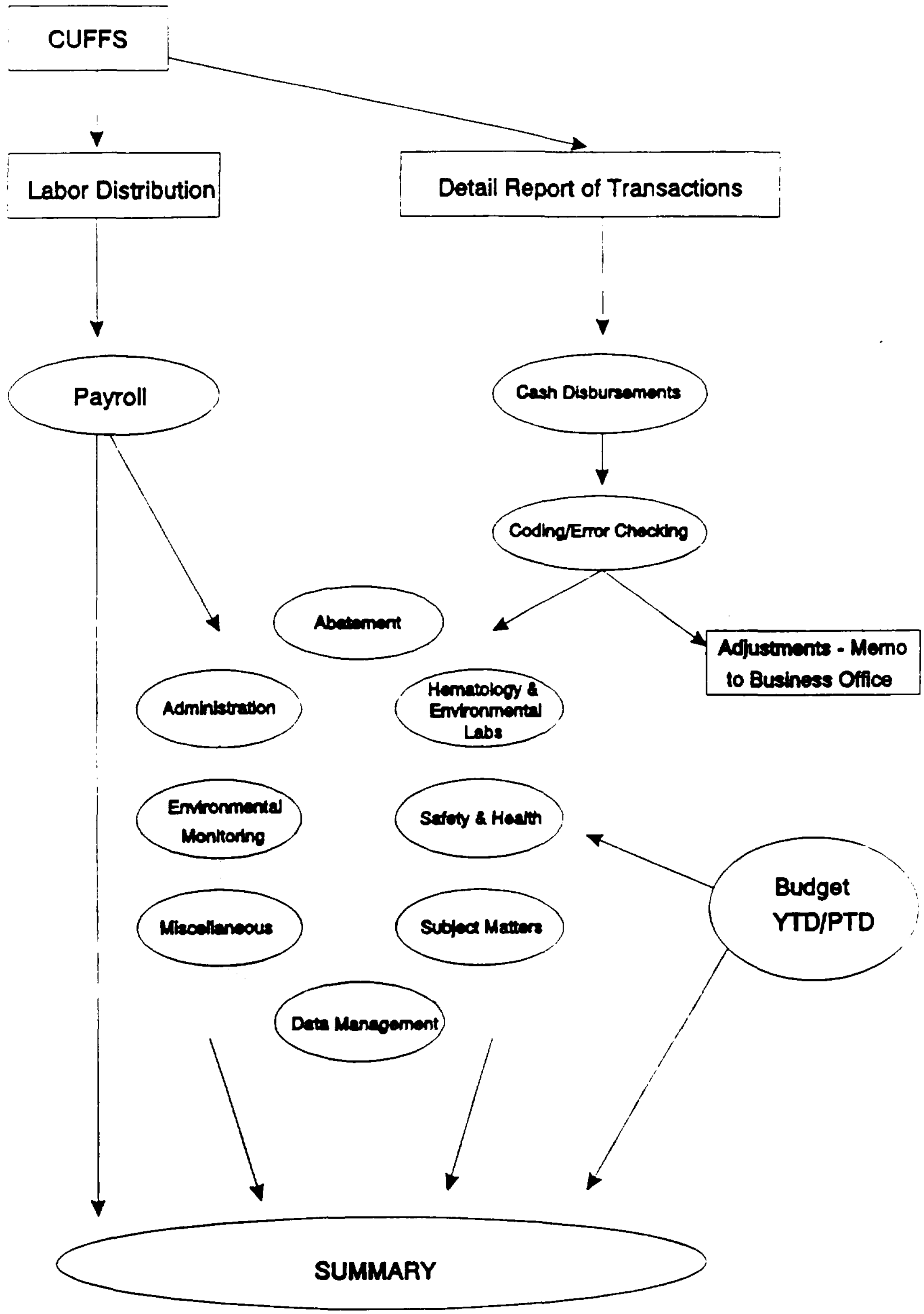


Figure 3-8. Cincinnati soil project—budget tracking system flow diagram.

Reports Generated by CUFS

Two reports included in the monthly packet of financial information that were used for our tracking system were the CUFS Budget Summary Report (Detail Report of Transactions) and the Labor Distribution Report.

Creating the Cash Disbursements and Payroll Files for the Budget Tracking System

We used each month's current information from the CUFS budget summary report and the labor distribution report as raw data to create the cash disbursements and payroll files for our tracking system. The information was retyped into a format specifically designed for our tracking system.

Current Expenses/Encumbrance Compared to Hard Copy Records

All encumbrances and expenses listed on CUFS were compared to hard copy records in the project files. Copies of requisitions, invoices, contractual agreements, time sheets and other documentation kept in our project files were checked and compared to confirm the accuracy of the entry. A brief description of the expense and the name of the person requesting the purchase were recorded to assist in determining the cost center, expense category, and type of expense.

Error Checking and Adjustments of Inaccurate Charges to Project Grant

All entries were error checked and any discrepancies found in the financial information were reported. Adjustments to the CUFS budget summary report and labor distribution report to correct inaccurate entries were processed through the Department of Environmental Health.

Cost Centers Summaries Updated With Current Financial Information

Individual cost center summaries were updated with the current month's expenses and encumbrances. Each cost center report included a comparison of actual to budget with a variance that indicated the unobligated amount for each line item in a year-to-date and project-to-date report.

Summary Report Updated With Current Financial Information

The summary report was also updated with the current's month's financial information and served as a summarization totalling the financial data contained in the individual cost summaries. The summary report included a comparison of actual to budget with a variance that indicated the unobligated amount for each line item in a year-to-date and project-to-date report.

Record Keeping

Each month's report was saved on diskette and a hard copy of the entire report filed with other financial records of the Cincinnati Soil Lead Demonstration Project.

Financial Reports

In addition to the information provided through the budget tracking system, a monthly financial report was presented to project investigators. The report contained a current month's comparison of expenses to budget using the on-line capabilities of CUFS. Additionally, projected spending through the end of the project period was included. This report was informative and assisted in decision making based on current information.

4. RESULTS

4.1 STUDY POPULATION

One hundred and eighty-four eligible families with children less than five years of age lived in the three study areas prior to study initiation. As a result of the high degree of interest among caregivers of the children and enthusiastic project staff, 146 families (225 children) agreed to participate in the study (Table 4-1). This represented 79% of the eligible families. In June 1990 (Phase 5) an additional 45 families (66 children) were recruited in areas B and C. They had moved into the study area after the initial recruitment but prior to soil-lead abatement which was scheduled for those areas. At the completion of the study (October 1991), 95 families with a total of 153 children were actively participating in the study. A summary of project enrollment (subjects, new births, families and dwelling units) by study Areas A (Pendleton), B (Findlay, Back and Dandridge) and C (Glencoe and Mohawk) appears in Appendix N. New births represent infants born into study families. The usefulness of their data depends on whether they entered the study before or after abatement and will be described later. The families recruited in June 1990 who were living in Area B had their interior abatements performed during the summer of 1990 along with the exterior (soil and dust) abatements which had been scheduled for Area B during the summer of 1990. Thus the subjects recruited in June 1990 (and living in Area B) were similar to those in Area A in that all three abatement procedures were implemented during the same period of time.

The initial data analysis will focus on the children who were recruited in June-July of 1989 and hereafter referred to as "initial recruits". As the study design stipulated, the focus of the recruitment was on children living in the rehabilitated housing (about 90% of the study population). The initial data analysis will, therefore, only include data for children living in rehabilitated housing. Analysis of results from area-wide sampling, such as for soil and exterior dust sampling on streets, sidewalks, alleys etc., will include all data regardless of the type of nearby housing.

The age of the initial recruits at the time of the first blood collection is shown in Table 4-2 by study areas.

TABLE 4-1. CINCINNATI SOIL PROJECT ENROLLMENT OF SUBJECTS

Area	Initial Recruitment[a]		Second Recruitment[b]	
	Number Enrolled (Phase 01)	Number Remaining (Phase 09)	Number Enrolled (Phase 05)	Number Remaining (Phase 09)
A	56 (36)[c]	23 (17)	not performed	not performed
B	107 (68)	47 (31)	29 (19)	16 (9)
C	62 (42)	30 (22)	37 (26)	21 (16)
Total	225 (146)	100[d] (70)	66 (45)	37[e] (25)

Total Recruited		Total Remaining (Phase 09)	
Phase 01 & 05	291	Phase 01 Recruits	100
Total New Births	16	Phase 05 Recruits	37
Total Subjects	307	New Births	16
			153

[a]June-July 1989 (Phase 01).
[b]June-July 1990 (Phase 05).
[c]No. families indicated in parenthesis.
[d]An additional 14 new births also participating in Phase 09.
[e]An additional 2 new births also participating in Phase 09.

TABLE 4-2. NUMBER OF STUDY PARTICIPANTS BY AGE RANGE (Phase 01, Rehabilitated Housing)

Age (years)	Area A	Area B	Area C
Less than 1	9 (18.4)[a]	17 (21.2)	11 (25)
1 - <2	10 (30.4)	17 (21.2)	7 (15.9)
2 - <3	10 (20.4)	13 (16.2)	9 (20.4)
3 - <4	10 (20.4)	15 (18.8)	7 (15.9)
4 - <5	10 (20.4)	13 (16.2)	6 (13.6)
5 - <6	0 (0)	5 (6.2)	4 (9.1)
Total	49	80	44

[a]Percentage for area shown in parentheses.

4.2 EXCLUSION FROM DATA ANALYSIS

The initial data analysis will focus only on children entered into the study during the initial blood collection period (Phase 01, June-July 1989) and who were living in rehabilitated housing. Therefore a number of children will not be included in the analysis presented herein: children recruited from Areas B and C during Phase 05 (June-July 1990, children living in non-rehabilitated housing, and children born in study families after older siblings had already been recruited ("new births"). In addition, four subjects were excluded who were identified as being chelated prior to entry into the study or pre-abatement or who were victims of careless remodeling work.

Children Recruited During Phase 05

A total of 66 children were recruited during Phase 05 (June-July 1990), 29 in Area B and 37 in Area C. The children recruited in Area B received all three types of abatement (exterior and interior dust and soil) during the summer of 1990. Thus, their abatement pattern is identical to that in Area A except that it was conducted one year later. In a future data analysis we will explore combining them with Area A children for the purpose of evaluating the impact of abatement.

Children Living in Non-Rehabilitated Housing

Thirty-one of the children recruited in Phase 01 (June-July 1989) are identified as living in non-rehabilitated housing: 2 in Area A, 18 in Area B and 11 in Area C.

The housing of most of these Area C children were initially misclassified as non-rehabilitated housing when it actually was rehabilitated. Re-coding will be conducted in the near future so that those children can be included in the analysis of children living in rehabilitated housing and who were recruited during Phase 01.

New Births

A number of children of study families were born during the study period. In many cases (16) we were successful in recruiting them into the study when they were only a few months old. In many cases they were born after some abatement in their home environments had already occurred. Data from those children will not be used as part of the primary data analyses but will only be used in special case study analyses and other special studies. Four of these children are in Group A, 10 in B and 2 in C.

Specifically Excluded Subjects

All data from four subjects who were either in housing undergoing renovation or who were lead poisoned prior to their entry into the study were removed from the data analyses.

Subjects 058 and 059. The apartment in which these children were living was undergoing paint removal by the owner resulting in excessive exposures to lead-containing dust. Hand lead values were 1,366 and 1,386 μg, respectively pre-abatement (June 1989). These values are almost an order of magnitude higher than any others we have seen. The family lived in Area B (Findlay sub-area) in a deteriorated non-rehabed 19th century building. We have three blood samples from each child. The family moved April 1990.

Subjects 812 and 813. These subjects were each chelated for lead poisoning during the summer of 1989 (July and August, respectively) prior to their entry into our study during our second recruitment in June 1990 (Phase 05). Subject 812 had a blood lead of 46 in August 1987 as determined by the Cincinnati Health Department.

4.3 SAMPLE COLLECTION AND ABATEMENT SCHEDULE

The overall abatement and monitoring time table for the Cincinnati project was previously shown in Figure 3-1. The specific types and locations of the samples collected during the ten sampling phases (00 to 09) were outlined in Figure 3-2. Certain reductions in sample collection and analyses that were necessary due to time constraints are indicated in Figure 3-2 for Phases 06, 07 and 09.

4.4 BLOOD AND ENVIRONMENTAL SAMPLE QUALITY ASSURANCE/QUALITY CONTROL RESULTS

Prior to the beginning of our study the precision and accuracy of each type of sample measurement was evaluated. Goals were established in terms of completeness and representativeness of study design. Coordination efforts among the three cities involved in the study resulted in the development of similar methods and protocols so that ultimately data comparability could be realized. However, the validity of the Cincinnati Soil Project results still depend in large part on the quality of sample collection and analysis. The results of the Quality Assurance/Quality Control (QA/QC) procedures implemented in our collection and analysis protocols are given in the following sections. Table 4-3 lists the different types of samples collected and analyzed, and the quality control associated with each type.

At the beginning of the study 28 fictitious family identities were developed. Identifiers were consistent with those used for the real study families. Except for soil and exterior dust all field QC samples were given study sample numbers and identified as being collected from one of the fictitious families. In this way, QC samples were submitted to the lab and analyzed with their true identity unknown. Soil and exterior dust QC samples were, on the other hand, distributed to the analyst without their associated location, building and family identifiers. Therefore, the true identity of those samples was also protected.

4.4.1 Quality Control Evaluation for Blood

The hematology QC program consisted of the following elements:

1. Field duplicates - fictitious families (a total of 28 fictitious children)
2. Blind control samples supplied by Centers for Disease Control (CDC) - lead (PbB)
3. Low and high isotope dilution mass spectrometry (IDMS) determined reference samples
4. College of American Pathologists (CAP) PbB proficiency program
5. CDC, PbB and free erythrocyte protoporphyrin (FEP) proficiency program
6. Bi-annual analysis of hematology controls for Hematocrit and Hemoglobin
7. Human reference sample for iron (Fe) and total iron binding capacity (TIBC)

The analytical methods used for each analyte were as follows:

1) PbB - Anodic Stripping Voltammetry
2) FEP - extraction followed by spectofluorometry
3) Serum Fe and TIBC - electrochemical
4) Hematocrit - centrifugation
5) Hemoglobin - calorimetric

TABLE 4-3. QUALITY CONTROL EVALUATIONS FOR EACH SAMPLE TYPE

1) Blood
   a. Field duplicates - fictitious families
   b. Blind control samples supplied by CDC - PbB
   c. Low and high ID-MS determined reference samples
   d. College of American Pathologists PbB proficiency program
   e. CDC PbB and FEP proficiency program
   f. Bi-annual analysis of hematology controls for Hematocrit and Hemoglobin
   g. Human reference sample for Fe and TIBC

2) Soil
   a. Field duplicates
   b. Field lab sieving blank
   c. Blind control samples supplied by EMSL - Las Vegas
   d. Low and High reference samples

3) Exterior Dust
   a. Field duplicates
   b. Field lab sieving blank
   c. Blind control samples supplied by EMSL - Las Vegas
   d. Low and High reference samples

4) Interior
   a. Field duplicates
      1. interior dust
      2. dustfall

   b. Field blanks
      1. interior dust
      2. handwipes

   c. Blind control samples supplied by EMSL - Las Vegas
      1. interior dust
      2. handwipe

   d. Lab method and reagent blacks
      1. interior dust
      2. handwipe
      3. dustfall

   e. Lab duplicate
      1. interior dust
      2. dustfall

   f. Lab controls
      1. interior dust
      2. handwipe
      3. dustfall

   g. AAS analysis- duplicates and % recovery
      1. interior dust
      2. dustfall
      3. handwipe

5) Water
   a. Field duplicates
   b. Field blanks
   c. Lab blank
   d. Lab control
   e. Lab duplicates
   f. % recovery

6) Paint
   a. Instrument blanks
   b. Instrument calibration checks

A field duplicate for blood was one half of a total sample drawn from an individual volunteer. Thus, approximately 8 ml of blood was collected from 1 person and dispensed into 2 EDTA-containing pediatric Vacutainer™ tubes and 2 vacutainers™ with no anticoagulant. Each set of two different tubes were labeled with one of the 28 fictitious identities and submitted to the lab for the complete series of analyses. Fresh field duplicates were collected at a rate of 2 individuals of 4 samples per week. The fictitous family indentifiers were repeated in each phase. This type of QC sample can only evaluate precision. Table 4-4 shows the results of the differences between duplicates for each test when samples were analyzed blind.

Four different concentration blood samples were supplied by the Centers for Disease Control to test for analytical or procedural variabilities within or among the three cities in the soil projects. Prior to the start of the study these samples were repeatedly analyzed by each city. Our assays were carried out in 13 separate daily runs at a rate of one run per week and over the time period from 1/31/89 to 5/9/89. A target value was then determined for each city's analysis of the sample and also a consensus value for the sample itself.

During the course of the study, at least two of the four samples were analyzed in duplicate with each set of unknowns. Of the four two were always blind to the analyst. The two blind samples were those with target values of 3.5 $\pm$ 8.9 μg/dL. Table 4-5 shows the results accumulated on these samples over the two years of the study.

In addition to the samples supplied by CDC for this project we continued to employ the techniques that are a part of the standard operating procedures of our laboratory. That included analyzing duplicate samples of 2 IDMS determined reference bloods with each set of unknowns. Limits were established for these samples to evaluate the validity of the analytical run, and control charts were kept to document performance over time.

If the concentration of two or more of the four samples fell outside the established limits, the run of PbB samples was rejected and all samples reanalyzed. This did not occur with any of our analytical runs. However, on two occasions the 5.3 μg/dL control in Phase 03 fell well beyond the 3 standard deviation or rejection criteria. Possible contamination of these QC samples was suspected. Listed in Table 4-6 are the averages, average differences between duplicates and the standard deviations for these IDMS samples in the Soil Project analytical runs.

TABLE 4-4. ABSOLUTE DIFFERENCE BETWEEN BLIND DUPLICATE ANALYSES OF THE SAME HUMAN BLOOD SAMPLES

Phase	Hematocrit	Hemoglobin	Serum FE	TIBC	% Saturation	PbB	FEP
	%	gm/dL	μg/dL	μg/dL	%	μg/dL	μg/dL
01 N=14 pairs	0.5	0.16	5.4	17	0.9	1.5	1.5
03 N=14 pairs	0.6	0.16	4.6	16	2.0	1.0	2.8
05 N=9 pairs	0.0	0.25	3.3	7	1.3	1.4	1.8
07 N=9 pairs	0.2	0.23	5.2	9	1.4	0.8	1.9
09 N=6 pairs	0.3	0.18	6.0	8	2.7	0.8	2.5

TABLE 4-5. BLOOD LEAD QUALITY CONTROL SAMPLES PREPARED BY CENTERS FOR DISEASE CONTROL FOR THE CINCINNATI SOIL LEAD PROJECT

	Target Value[a] Consensus Value[b]	3.5 4.3	8.9 10.3	2.5[c] 1.6	43.3 44.9	SLOPE	Y-INTERCEPT	r^2
	DATE SAMPLE COLLECTED							
Phase 01	6/7/89-8/10/89	5.1	9.4	2.6	42.2	0.9526	0.9643	0.9994
Phase 03	10/16/89-12/7/89	3.7	8.2	1.7	43.3	1.010	-0.4721	0.9997
Phase 05	6/18/90-7/24/90	4.3	8.6	2.2	42.4	0.9739	0.2050	0.9997
Phase 07	11/7/90-12/10/90	4.5	8.4	2.9	43.0	0.9808	0.4300	0.9995
Phase 09	6/10/91-8/8/91	4.2	8.9	3.5	43.5	0.9875	0.6564	0.9998
N		33	28	60	60			
Mean		4.4	8.8	2.5	42.7			
S.D.		1.2	1.2	0.9	1.1			
C.V.		28	13	36	3			
Min.		2.3	6.6	0.5	40.1			
Max.		8.0	11.0	4.9	45.3			

[a]Target Value established by U.C. lab prior to the study.
[b]Four Lab Consensus Value; U.C.; CDC; ESA; MO. DOH.
[c]This sample was analyzed as a blind control throughout the study.

TABLE 4-6. LABORATORY PERFORMANCE IN THE ANALYSIS OF ISOTOPE DILUTION MASS-SPECTROSCOPY REFERENCE SAMPLES

	I.D.M.S. Target Value = 5.3 μg/dL					I.D.M.S. Target Value = 40.4 μg/dL				
Phase	**N**	**Mean of all Values**	**S.D.**	**Difference Between Duplicates**	**S.D.**	**N**	**Mean of all Values**	**S.D.**	**Difference Between Duplicates**	**S.D.**
01	36	6.3	0.9	-	-	36				
	18	-	-	0.8	0.7	18	40.2	1.5	1.1	0.8
03	20	5.2*	0.6	-	-	22				
	9	-	-	0.8*	0.3	11	40.5	1.7	1.9	1.0
05	25	5.6	0.7	-	-	22				
	12	-	-	0.7	0.6	10	40.5	1.1	1.0	0.6
07	20	5.8	0.8	-	-	20				
	10	-	-	0.6	0.5	10	41.5	1.1	1.0	0.7
09	18	6.1	0.9	-	-	18				
	9	-	-	0.7	0.7	9	42.0	1.6	1.2	0.8

*2 Outliers excluded.

Participation in two proficiency programs is another ongoing process in our labs. Samples are provided by the Center for Disease Control on a monthly basis for PbB and FEP determinations. Lead samples are supplied quarterly by the College of American Pathologist proficiency program. Our results are compared to consensus values established by reference and participating laboratories for these programs. Figure 4-1 and 4-2 show our performance in these programs for PbB over the two year interval during which this study was run. Figure 4-3 illustrates the results for FEP in the CDC program.

Hematology controls were purchased periodically during the Soil Project and used to evaluate hematocrit and hemoglobin concentrations. Purchased from Fisher Scientific Company, these controls closely resemble patient's whole blood samples and so provide a control for the two methods. There are target values assigned to the samples which were obtained using a number of automated instruments and manual methods. Four sets of these samples were analyzed and the comparison is shown in Table 4-7.

Serum Fe and TIBC analysis were monitored by analyzing the same human serum sample during each day's analytical run. The serum was a pooled sample collected from one individual, aliquoted into separate tubes and frozen. Each sample pool was only stable for approximately 6 mo. Therefore, prior to its expiration date another sample pool was developed. Thus, pools were overlapped to maintain continuity. These samples provide measurement of precision and a check for instrument or calibration drift. Table 4-8 shows data generated during the Soil Project study time frame.

4.4.2 Quality Control Evaluations for Soil X-ray Fluorescence

The soil QC program consisted of the following elements:

1. Field duplicates (co-located samples)
2. Field lab sieving blank
3. Blind control samples supplied by Environmental Monitoring Systems Laboratory (EMSL) - Las Vegas
4. Low and High reference samples

As was to be expected, soil field duplicates (co-located samples) were at best a rough estimate of the concentration of the original sample collected. Duplicates were collected for

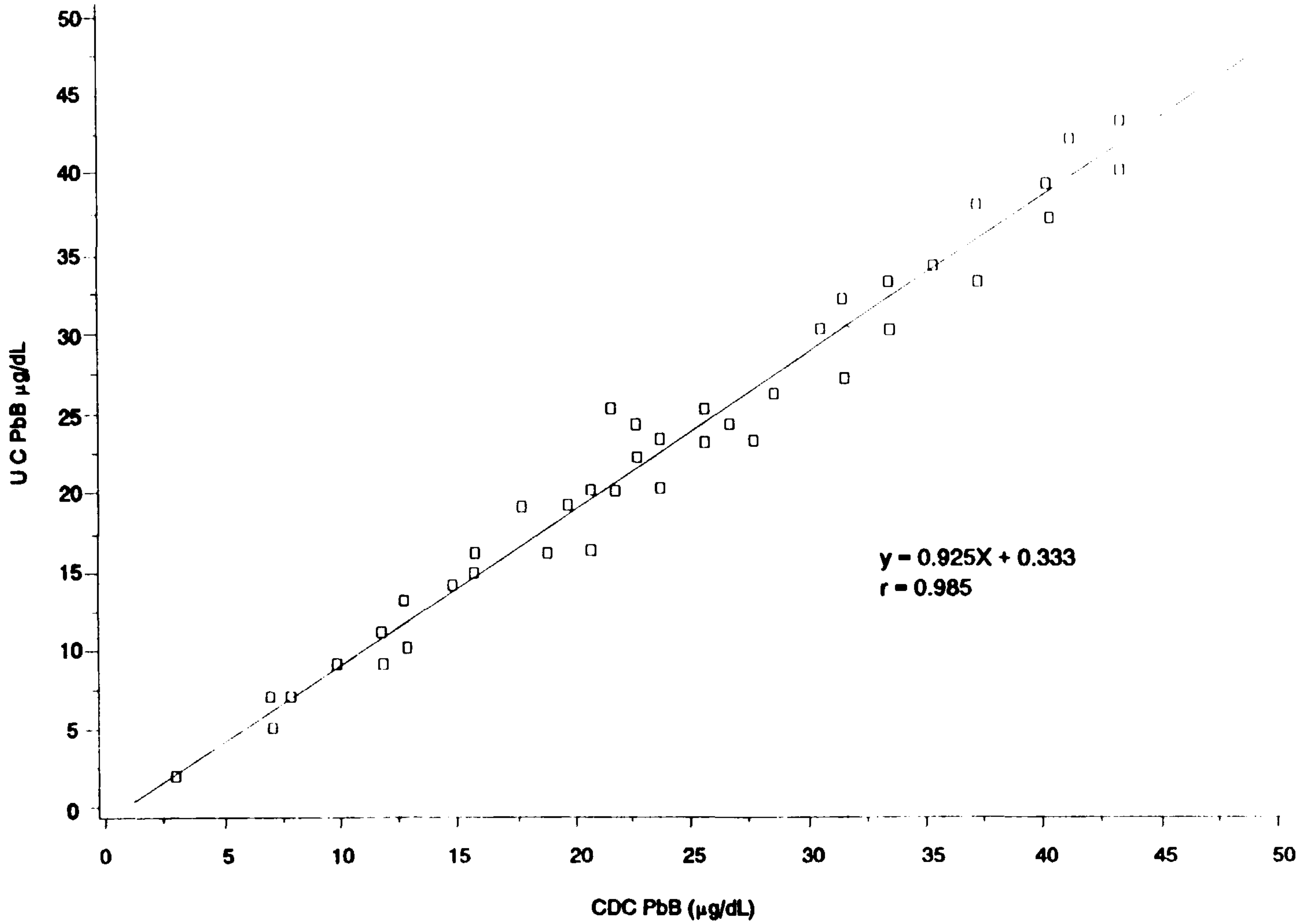


Figure 4-1. Performance of the Cincinnati project in the Centers for Disease Control proficiency program for blood lead analysis during the period June 1989 to September 1991.

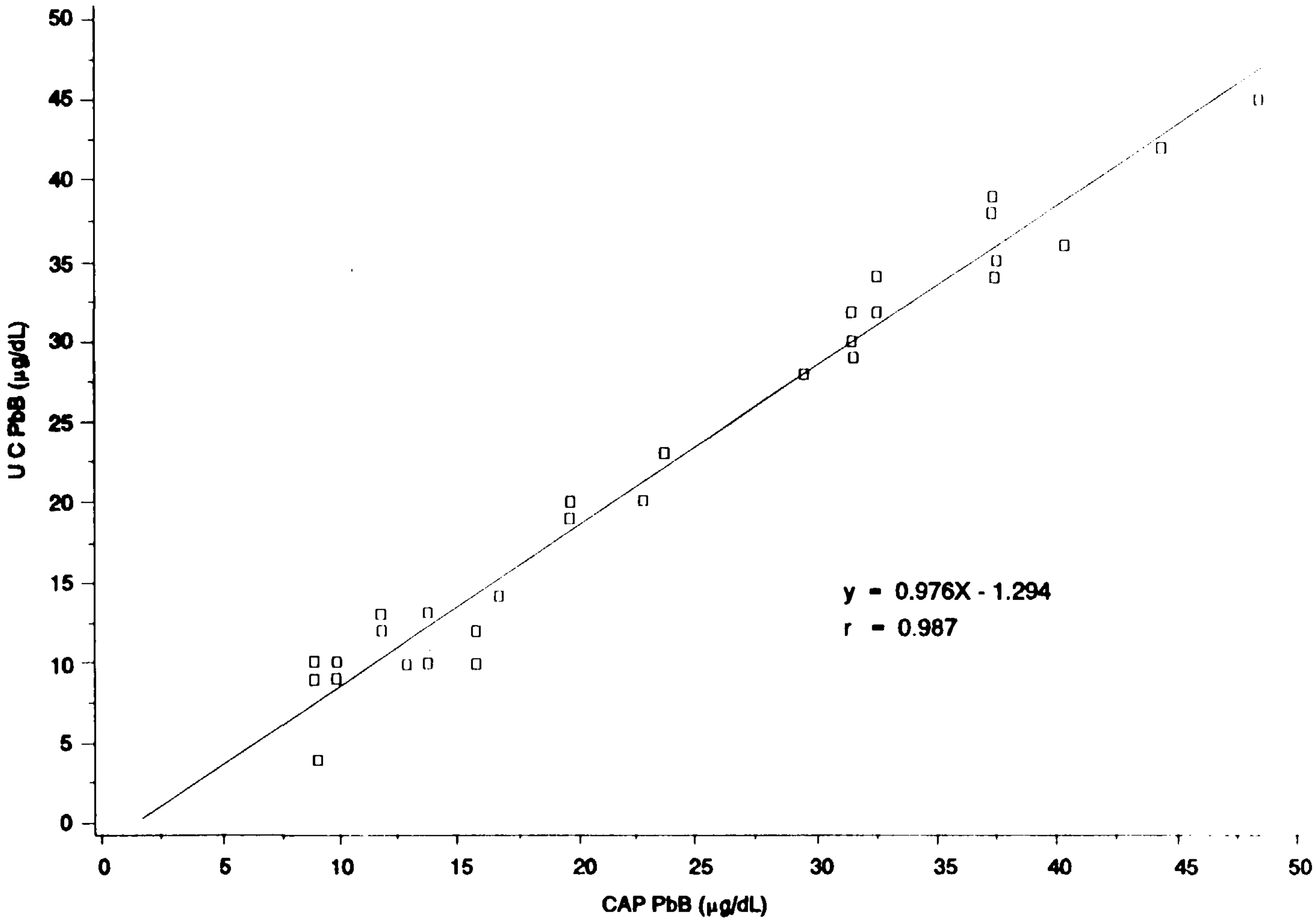


Figure 4-2. Performance of the Cincinnati project in the College of American Pathologists proficiency program for blood lead analysis during the period June 1989 to September 1991.

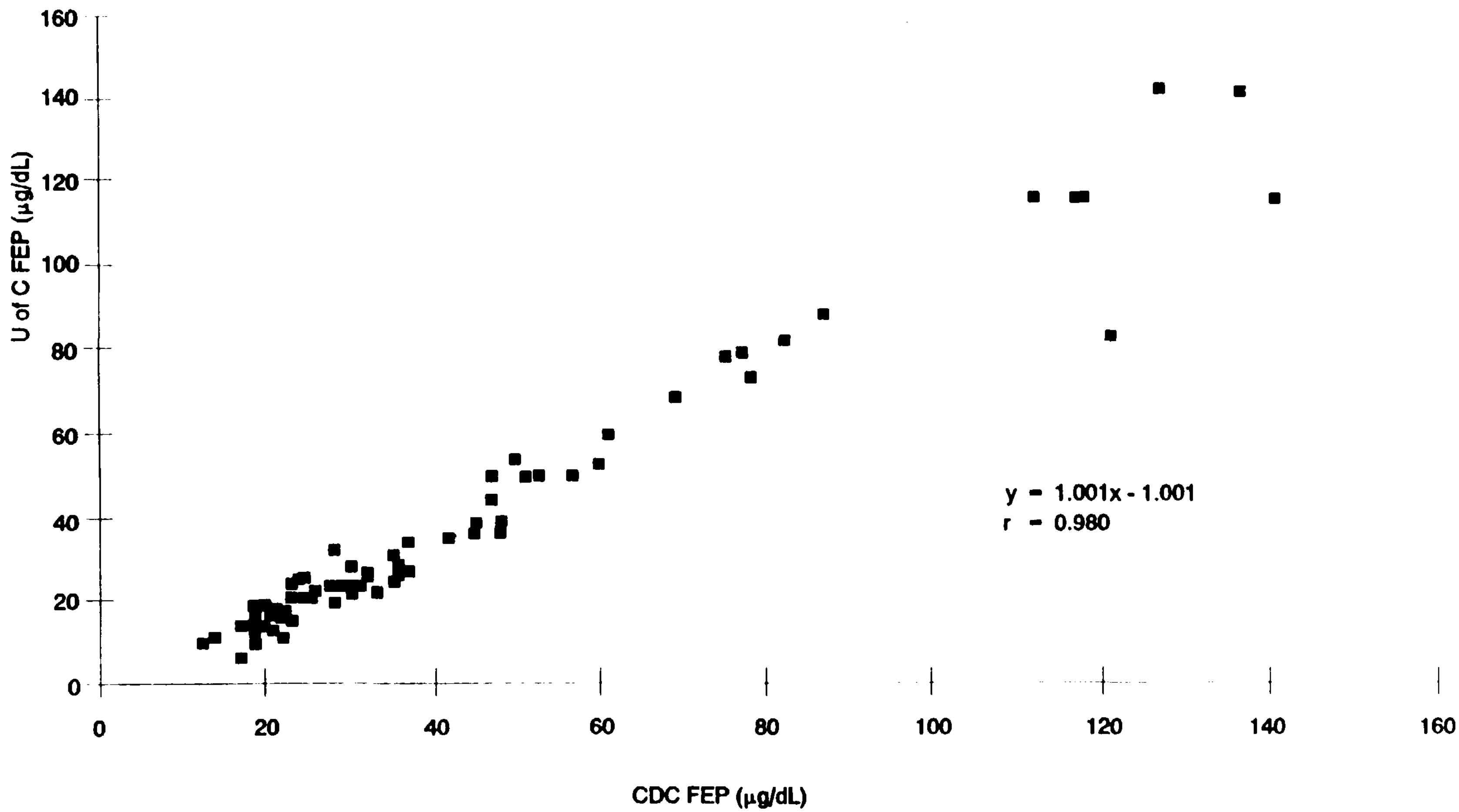


Figure 4-3. Performance of the Cincinnati project in the Centers for Disease Control proficiency program for free erythroporphyrin (FEP) analysis during the period June 1989 to September 1991.

TABLE 4-7. UNIVERSITY OF CINCINNATI PERFORMACE IN THE ANALYSIS OF HEMATOLOGY CONTROLS

Lot #	HEMATOCRIT (%)				HEMOGLOBIN (g/dL)			
	Fisher (Target Value)		University of Cincinnati Results		Fisher (Target Value)		University of Cincinnati Results	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Lot 1 (Phase 1)	34.3	3.0	33.6	0.5	11.7	0.8	11.4	0.1
Lot 2 (Phase 3)	33.9	3.0	33.3	0.5	11.8	0.8	12.0	0.2
Lot 3 (Phase 5)	30.5	2.0	28.9	0.6	12.3	0.5	12.4	0.4
Lot 4 (Phase 7)	30.5	3.0	29.3	0.7	12.3	0.8	12.5	0.4

TABLE 4-8. SERUM IRON AND TOTAL IRON BINDING CAPACITY SERUM POOLS

Identity	Number of Analyses	Serum FE		TIBC		% Saturation	
		$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Lot-M4*	16	57.9	2.2	305	13	18.9	1.0
Lot M5	16	110.4	5.8	309	20	35.9	1.3
Lot M6	18	80.6	3.9	301	13	26.8	0.8

*Human samples; no target value.

one out of every 10 unknowns and not necessarily done on the same day. They were, however, collected within 6 mo.

Field Lab Sieving Blanks consisted of material obtained from a sand/gravel quarry in Cincinnati. These materials were previously determined to be very low lead content (Que Hee et al., 1985). There were three types of native soils analyzed:

Blank #1. Lake bed clays possibly Wisconsin glacial stage 20-25,000 years old.

Blank #2. Illiniosian Till, 125,000 years old.

Blank #3. Pre-glacial Fluevial (river) sand, 150,000 years old.

They were sieved to $<250\ \mu$ particle size and randomly inserted in the unknown sample stream. Results are shown in Table 4-9.

TABLE 4-9. SOIL FIELD LAB BLANKS

Blank #	N	$\bar{X}$	S.D.	Minimum Value	Maximum Value	C.V.
1	90	11.0	10.6	0.9	54.8	96
2	116	14.4	11.0	0.9	65.2	76
3	94	15.1	8.9	3.5	53.9	59

Study control samples for soil analysis were provided by EMSL - Las Vegas and provided to each of the three Soil Projects. The raw samples were collected in each city and shipped to EMSL where they were sieved, analyzed, and redistributed to the projects. These soils were randomly inserted into the study's sample stream and analyzed unknown to laboratory staff.

An X-ray Spectrometer (XRF) and Atomic Absorption Spectroscopy (AAS) concensus value for the samples was determined in a round robin exchange among the cities. Also from these data a correction factor for each city was calculated. The factor when applied to all soil results yielded comparable data among the three projects. The following table (Table 4-10) gives the results of our analysis, the corrected concentration and the concensus value determined by the round robin exchange for the particular QC samples used in our study. Our labs digestion and AAS values for three of the samples was: Bos M=6,937, Cin H=13,195 and Cin L=379.

Two reference control samples were placed within each set of 16 samples analyzed on the KEVEX XRF instrument. Their average concentration as determined by repeated analysis was 170 ppm and 1066 ppm of Pb. A 2 standard deviation limit was set as rejection

TABLE 4-10. UNIVERSITY OF CINCINNATI LAB PERFORMANCE IN ANALYZING ENVIRONMENTAL MONITORING SYSTEMS LABORATORY QUALITY CONTROL SOIL SAMPLES BY X-RAY SPECTROMETER[c]

	N	$\bar{X}$ (ppm)	S.D.	C.V.	Corrected $\bar{x}^{a}$ (ppm)	Consensus Value[b] (ppm)
Bal M	49	1,016	40	4	884	-
Bos M	32	6,654	268	4	5,788	6,175
Cin H	31	14,890	635	4	12,951	12,499
Cin L	130	301	11	4	262	335

[a] $\bar{x}$'s were multiplied by the constant 0.8698 determined by the intercalibration study to adjust for "within" variance.
[b] Consensus value for soil samples determined by XRF using the multiplicative model with weight = 1.
[c] Data are from QC samples analyzed during phases 2, 3, 5, and 9.

criteria and subsequently any XRF run of samples with one or more of these QC samples outside of the established range was re-analyzed.

4.4.3 Quality Control Evaluation for Exterior Dust

The exterior dust QC program consisted of the following components:

1. Field duplicates (co-located samples)
2. Field lab sieving blank
3. Blind control samples supplied by EMSL - Las Vegas
4. Low and High reference samples

The Quality Control used for the exterior dust was the same type as used for the soil. Duplicates were collected for one out of every 10 unknowns. Field lab sieving blanks were the same material as used for the soil. The EMSL-Las Vegas QC were also soil material of the concentrations used with soil. These were all dispersed randomly throughout the exterior dust samples. The reference controls were also the same samples. Table 4-11 shows the concentrations of the blanks prepared with the exterior dust and Table 4-12 performance on analysis of EMSL QC samples (compare with Table 4-10).

TABLE 4-11. EXTERIOR DUST FIELD LAB BLANKS

Blank #	N		S.D.	Minimum Value	Maximum Value	C.V.
1	44	24.5	4.9	6.1	30.4	20
2	44	28.0	8.1	13.0	64.4	29
3	45	22.7	6.5	9.6	26.3	29

TABLE 4-12. ENVIRONMENTAL MONITORING SYSTEMS QUALITY CONTROL SOIL SAMPLES ANALYZED WITH EXTERIOR DUST SAMPLES
(Phases 1,2,3,5 and 9)

N	$\bar{X}$ (ppm)	S.D.	C.V.	Corrected $\bar{X}$[a]	Consensus Value[b] (ppm)
48	1,015	43	4	883	
24	6,630	326	5	5,757	6,175
23	14,582	826	6	12,683	12,499
117	314	56	18	273	335

[a] $\bar{x}$'s were multiplied by the constant 0.8698 determined by the intercalibration study for "within" lab variance
[b] Consensus value for soil samples determined by XRF using the multiplicative model with weight = 1. The bi-weight range is currently being determined.

4.4.4 Quality Control Evaluations for Interior Dust

The interior dust QC program consisted of the following components:

1. Field Duplicates
2. Field Blanks
3. Blind control samples supplied by EMSL - Las Vegas
4. Lab method and reagent blanks
5. Lab duplicates
6. Lab controls
7. AAS analysis - duplicates and % recovery

Interior dust duplicates were collected at one every 25 residences at a spot adjacent to the study sample site. Table 4-13 shows the average difference between those results for each sample type and within each collection phase.

TABLE 4-13. PERFORMANCE ON ANALYSES OF ENVIRONMENTAL MONITORING SYSTEMS LABORATORY QUALITY CONTROL DUST SAMPLES

	N	$\bar{X}^a$ (ppm)	S.D.	C.V.	Consensus Value[b]
Bal ML	34	1,727	275	16	1,492
Bos H	35	24,104	2,337	10	N/A
Cin L	26	259	44	17	232
Cin MH	38	2,683	225	8	2,378

[a] $\bar{x}$'s were multiplied by the constant 0.9839 determined by the intercalibration study for "within" lab variance.
[b] Consensus value for soil samples determined by XRF using the multiplicative model for "within" lab variance.

Field blanks were collected during the last four phases of the project. These consisted of setting the pump on a table with the nozzle pointed upward and collecting air into an empty sampling cassette for 3 min. The concentration range of 44 blanks was 0.11 - 1.75 μg Pb with an average of 0.48 μg/Pb $\pm$ 0.35. Three samples had a Pb concentration greater than 1.0 μg and were considered contaminated. The sample weights were all very low - < 0.0009 g.

Samples prepared by EMSL - Las Vegas were disguised using fictitious family identities and sent to the laboratory. The samples, shipped from EMSL, were sampling cassettes containing a known amount of standard dust. They were inserted into the studies sample stream at the field office.

The laboratory handling of the interior dust samples was a fully controlled process in which validity of the data was determined by whether or not blanks and controls fell within established weight or concentration limits. The limits were calculated using the results of the first 25 assays of each QC type. If more than three of the six QC samples in a run were outside of the defined limits, the entire set was considered invalid. In this project 154 sets of interior dust samples were analyzed. Three interior dust sets (2%), of 22 unknowns each, were not acceptable according to these QC criteria.

The initial preparation of the samples was very important. Due to the small sample size collected by our vacuum method, the accuracy of the weight measurement was critical. Weight corrections were applied to all unknowns in a set if blank values were > 1 standard deviation (SD) and <2 SD of an earlier determined average method blank weight nf both blank weights were >2 SD of the average method blank weight, then the QC sample was considered out of limits. All samples were digested and analyzed after weight measurements were determined, however, samples that weighed less than 0.002 grams (n = 45; 1.8%) were not calculated in ppm. Average weights for the Soil Project dust samples for each type of interior dust in each phase are shown in Table 4-14.

TABLE 4-14. AVERAGE WEIGHTS OF INTERIOR DUST SAMPLES (Grams)

Phase	Entry $\bar{X}$	Floor $\bar{X}$	Window $\bar{X}$	Mat $\bar{X}$
01	0.0567	0.0435	0.1164	0.0115
02	0.0227	0.0279	0.0690	0.0479
03	0.0350	0.0350	0.0386	0.0739
05	0.0750	0.0672	0.1859	0.0596
09	0.0700	-	-	-

(Total number of samples = 2,490).

There are several types of blanks in our preparation and digestion procedure for interior dust analysis. These include the method blank, preparation reagent blank and digestion reagent blank. The purpose of all of these samples are two fold: (1) to determine the true amount of weight or lead that is present in the unknown samples, and (2) to detect the presence of contamination in the collection, preparation, and digestion of study samples unknowns.

Method lab blanks consisted of blank cassettes loaded with filter and support pads and from the same lot of cassettes as used for the unknowns. These blanks were inserted during the evaporation or preparation stage of each day's set of samples. A reagent blank was also inserted at this point in each set and was actually a pre-weighed beaker of 50 ml of deionized/distilled H_20. Another reagent blank was introduced during the digestion step. This was done at a rate of one per day and was simply an empty beaker handled as a sample beaker.

The amount of lead in the method lab blanks ranged from 0.14-4.31 μg Pb found. Eight of 128 were >1.0 μg Pb - the rejection limit. Preparation reagent blanks ranged from 0.13 to 10.0 μg of Pb found with nine of 128 samples exceeded the rejection limit of >1.0 μg of Pb. The digestion lab blank had seven values of 128 not accepted and ranged in concentration from 0.13 to 4.17 μg Pb per sample.

There were two National Institute for Standards and Technology (NIST) standards used to track the accuracy of the interior dust method. They were standard #1648 Urban Particulate with a known Pb concentration of 6,550 ppm and Standard # 1646 Estuarine Sediment of concentration 28.2 ppm. One of the NIST Standards (#1646 or #1648 arbitrarily chosen) and duplicates of either of the reference samples were chosen to be incorporated into the initial preparation of the samples. Approximately 50 mg of each standard dust was weighed into a clean cassette and resealed. Prior to digestion of the samples 50 mg of the NIST standard, the same as was added to the prep stage of that set, was weighed into a beaker and digested along with other samples of the set. These gave us the means needed to track the handling and analysis of the samples. In addition, two bulk dusts taken from homes in the Cincinnati area were used to track the precision of the method over the course of the study. These latter QC samples were intended to be more valid urban dust standards than the NIST standards (Table 4-15).

The performance of the AAS instrument was also subject to QC monitoring. One in every 25 samples was analyzed in duplicate. Every 20th sample was used to determine percent recovery. The average difference between 160 duplicates was 1.42 $\pm$ 1.85 μg. The percent recovery calculated from 189 spiked samples averaged 102.2% $\pm$ 5.6.

4.4.5 Quality Control Evaluations for Interior Dustfall

The interior dustfall QC program (Table 4-16 and 4-17) consisted of the following components:

1. Field duplicates
2. Lab method and reagent blanks
3. Lab duplicates
4. Lab controls
5. AAS-duplicates and percent recovery

TABLE 4-15. SOIL PROJECT INTERIOR DUST QUALITY CONTROL STANDARDS
(Floor and Window)

Sample	Stage of Analysis	N	$\bar{X}$ (ppm)	S.D.	C.V.
NIST 1,646	Prep Digestion	105	28.2	4.7	16.6
(28.2 ppm)		57	28.2	3.6	12.8
NIST 1,648	Prep Digestion	46	7,052	528	7.5
(6,550 ppm)		19	6,946	318	4.6
REFERENCE LO	Prep Digestion	118	279	52	18.5
		23	281	39	14.0
REFERENCE HI	Prep Digestion	113	2,802	191	6.8
		28	2,766	133	4.8

TABLE 4-16. INTERIOR DUSTFALL FIELD DUPLICATES

Sample #	ppm Pb	Sample #	ppm Pb
211	454	260	210
212	152	261	74
285	14	160	47
286	23	161	305
311	44	136	353
312	122	137	356
236	482	186	103
237	572	187	40

TABLE 4-17. QUALITY CONTROL STANDARDS ANALYZED WITH DUSTFALL SAMPLES

Sample	Stage of Analysis	N	$\bar{X}$ (ppm)	S.D.	C.V.
NIST 1646	Prep Digestion	12	34.5	6.2	18
(28.2 ppm Pb)		13	28.9	4.1	18
Reference Lo	Prep	11	314	3.8	12
Reference Hi	Prep	14	2,960	210	7

Interior dustfall samples were collected during two phases of the Soil Project - Phase 02 and 06. Field duplicates but not field blanks, were obtained at one in every 25 residences in Phase 06. The comparison of the resulting eight duplicates is listed below.

The laboratory quality control was identical to that for the interior dust samples. There was a method blank or empty container prepared as a sample. Reagent blanks were inserted at each stage of sample handling and NIST and reference standards were used to track the accuracy of the method.

The concentration of all blanks was below the 1.0 μg Pb rejection limit. The NIST standard inserted into the analyses was Standard #1646 Estuarian Sediment containing 28.2 ppm Pb. Low and high Pb concentration reference samples were also used. Out of 13 sets analyzed no sets had to be rejected. The standards are tabled in Table 4-17 and can be compared with the standards and performances reported in Table 4-16.

The average difference for AAS analysis of duplicates was 1 $\pm$ 0.5 μg Pb. The average percent recovery of spiked samples was 104% $\pm$ 4.9.

4.4.6 Quality Control Evaluations for Hand Lead

The hand lead QC program consisted of the following components:

1. Field blanks
2. Blind control samples supplied by EMSL-Las Vegas
3. Lab method and reagent blanks
4. Lab controls
5. AAS-duplicates and percent recovery.

The acquisition and analysis of field blanks is very important to the evaluation of the quality of the unknowns associated with it. Proper handling and documentation of the wipes used is critical to that evaluation. In the Soil Project field blank limits were set at 0 $\pm$ 6 μg Pb based on using the 2 standard deviation value for the lab reagent blank. Thus, any field blank concentrations greater than 6 μg indicated contamination and rendered its associated sample or samples invalid. In addition, samples with a field blank less than 6 μg would be invalid due to suspicions such as samples containing less than 6 total wipes or using the wrong lot of material to collect the sample. There were 2,369 handwipe samples analyzed including field blanks and of the samples 55 were invalid based on the field blank concentration.

Hand lead control samples were prepared by the EMSL-Las Vegas lab and sent to Cincinnati for incorporation into the Soil Project samples. These samples contained aqueous lead solution of various concentrations aliquoted onto six wipes. The samples included clean wipes for use as field blanks. Before being sent to the lab the samples were labeled with the fictitious family identities. Table 4-18 shows the results of those samples.

TABLE 4-18. ENVIRONMENTAL MONITORING SYSTEMS LABORATORY QUALITY CONTROL HAND LEAD SAMPLES

Concentration Level (μg)	N	$\bar{X}$	S.D.	C.V.	Concentration* Added by EMSL (μg)
O	94	0.1	2.7	5,086	0
L	38	4.8	2.6	54	5
M	36	17.8	4.0	23	20
H	38	38.0	9.7	26	40

*The amount of lead added to the wipes is yet to be obtained from the EMSL-Las Vegas lab.

Lab reagent blanks were deemed invalid if <0 or >3 μg of lead was found. Only one out of 140 blanks was found to be invalid. Method lab blanks were used to correct all samples by the amount of lead present in clean wipes. The value subtracted was the average Pb concentration for all samples by the amount of lead present in clean wipes. The value substracted was the average Pb concentration for all method blanks determined from the same lot of wipes. There were different lots of wipes used in the Soil Project Study and their lab blanks ranged in concentration from 5-23 μg Pb per 6 wipes (no. of wipes used per child).

Lab controls were blank wipes spiked with a standard level lead solution. The concentrations used were 4, 20, 40 and 100 μg/ml. To check the quality and concentration portions of the stocksolution of each control were analyzed periodically by AAS. Limits were established for all controls and used in the validation of the sample set. If 2 or more controls or blanks were found to be outside of the established limits, the set was found to be invalid. Eight out of 140 sets could not meet the QC criteria. Two sets of 22 unknowns (including field blanks) were excluded entry from the data base (less than 2%) while six sets were included, but qualified.

Analytical duplicates and spiked recoveries were determined by the AAS analyst. One in every 25 samples or hand leads were analyzed in duplicate and the average difference between duplicates was 0.37. The percent recovery calculated from 150 spiked samples averaged 102 ± 6.

4.4.7 Quality Control Evaluations for Water

The water QC program consisted of the following elements:

1. Field duplicates
2. Field blanks
3. Blind lab controls
4. Lab duplicate and percent recovery.

Water samples were collected from the residences during Phase 04 and 08 of the study. Excluding field blanks and duplicates there were 278 water samples analyzed. Duplicates were collected at 10% of the homes with a total of 26 samples collected at 13 residences during both phases. The following Table 4-19 lists the study samples and their duplicates.

Field blanks were collected at 5% of the residences and totalled 10 samples. All values were <1.6 μg/dL. There were 2 concentration level controls incorporated into the unknown samples, sent to the lab and analyzed blind. The results of these samples for both phases are seen in Table 4-20.

All water samples were analyzed in duplicate and all were spiked and recovery of Pb calculated. Since such a large percent of the sample concentrations fell below the detection limit the average difference between duplicates was calculated using all duplicates greater than 1.6 μg/L. That difference was 0.4 ± 0.4 for 71 samples with a mean percent recovery of these samples of 98% ± 4.

4.4.8 Quality Control Evaluations for Paint

The following QC program was used for determining the concentration of lead in paint using a portable XRF:

TABLE 4-19. COMPARISON OF DUPLICATE WATER COLLECTIONS

Sample Type	Apt #	Study Sample (μg/L)	Duplicate (μg/L)
W1	008	<1.6	<1.6
W2	008	<1.6	<1.6
W1	063	<1.6	<1.6
W2	063	<1.6	<1.6
W1	137	<1.6	<1.6
W2	137	<1.6	<1.6
W1	151	3.0	2.2
W2	151	<1.6	<1.6
W1	054	<1.6	<1.6
W2	054	<1.6	5.6
W1	089	<1.6	<1.6
W2	089	<1.6	<1.6
W1	001	<1.6	<1.6
W2	001	<1.6	<1.6
W1	015	<1.6	<1.6
W2	015	<1.6	<1.6
W1	024	<1.6	<1.6
W2	024	<1.6	<1.6
W1	226	11.1	<1.6
W2	226	<1.6	<1.6
W1	207	3.3	<1.6
W2	207	<1.6	<1.6
W1	227	<1.6	<1.6
W2	227	<1.6	<1.6
W1	223	7.9	8.3
W2	223	37.3	21.0

TABLE 4-20. QUALITY CONTROL WATER SAMPLES ANALYZED BLIND

Known Concentration (μg/L)	Number Analyzed	$\bar{X}$ (μg/L)	S.D.	C.V.
10	4	10.3	0.62	6
27	13	28.2	2.00	7

1. NIST reference lead film calibration checks.
2. Triplicate readings at each sampling point.

4.5 SOIL LEAD CONCENTRATIONS

Soil lead concentrations by sampling phase, sample type (surface, top and bottom) and study area are presented in Table 4-21 and Figures 4-4, 4-5 and 4-6. Geometric mean values, upper and lower confidence limits, 95%-tile values and number of samples are presented. Soil abatement occurred in Area A just prior to Phase 2 sample collection (Sept.-Oct. 1989) and just after Phase 5 sample collection (June-July 1990) in Area B. As planned, the final soil lead sampling in Area C (Phase 09, June-Aug. 1991) occurred just prior to Area C soil abatement.

Abatement Impact

Pre- and post-soil abatement soil lead concentrations in Area A are represented by samples collected in Phases 00 and 02, respectively. Soil lead abatement in Area A resulted in a decrease in the geometric mean lead concentration of 140 ppm in the composite surface scrapings, 146 ppm in the top 2 cm composite core samples and 113 ppm in the bottom 2 cm composite core samples. The 95%-tile soil lead concentration in the top 2 cm decreased from 2,695 ppm to 422 ppm. The decreases are statistically significant ($p < 0.05$) as indicated by the 95% confidence limits which do not overlap. Soil lead concentrations did not decrease between Phases 00 and 02 in Area B and C where soil lead abatement did not occur between these sample collection phases.

The effects of soil lead abatement in Area B, which occurred during the Aug.-Sept. 1990 period can be seen by comparing top 2 cm composite core lead soil lead concentration from Phase 05 samples (June-July 1990) and Phase 09 samples (June-July 1991). Soil lead abatement in Area B was associated with a decrease in the geometric mean soil lead concentration of 102 ppm.

TABLE 4-21. SOIL LEAD CONCENTRATIONS
(All Sampling Patterns)

Phase	Area A G.M. (LCL-UCL)	Area A 95%-tile (n)	Area B G.M. (LCL-UCL)	Area B 95%-tile (n)	Area C G.M. (LCL-UCL)	Area C 95%-tile (n)
A. Surface Scrapings						
00	189 (158–226)	1,996 (242)	101 (90–114)	776 (273)	154 (135–177)	1,653 (311)
	SOIL ABATEMENT AREA A					
02	49.4 (39.5–61.8)	260 (55)	155 (134–179)	1,572 (281)	126 (105–150)	1,759 (179)
03	59.3 (43.4–81.0)	532 (51)	122 (105–143)	1,258 (192)	110 (92.2–131)	979 (171)
B. Top 2 cm Core Composite Samples						
00	200 (162–245)	2,659 (195)	103 (91–116)	780 (230)	140 (119–164)	1,200 (224)
	SOIL ABATEMENT AREA A					
02	54.0 (46.1–63.3)	422 (160)	148 (133–164)	1,192 (369)	163 (139–191)	1,347 (241)
03	44.3 (37.4–52.4)	403 (160)	161 (143–180)	1,729 (385)	170 (142–203)	1,902 (235)
05	51.8 (44.3–60.7)	430 (155)	161 (144–180)	1,509 (380)	145 (124–169)	1,394 (232)
			SOIL ABATEMENT AREA B			
09	58.8 (49.7–69.7)	660 (159)	59.5 (54.5–64.9)	249 (372)	161 (137–190)	1,345 (232)
					SOIL ABATEMENT AREA C	
C. Bottom 2 cm Composite Samples From 15 cm Cores						
00	215 (176–262)	1,612 (185)	62.4 (56–70)	383 (230)	114 (98–133)	848 (217)
	SOIL ABATEMENT AREA A					
02	102 (69.8–151)	760 (42)	103 (87.6–122)	1,162 (203)	114 (90.1–144)	1,044 (89)
03	91.8 (56.4–150)	1,503 (43)	70.4 (56.2–88.0)	897 (125)	86.9 (66.3–114)	813 (87)

GM = geometric mean; LCL = lower confidence limit of geometric mean; UCL = upper confidence limit of geometric mean.
Total Number of Samples: surface scrapings (1,755); top 2 cm composites (3,729); bottom 2 cm composites (2,218); total = 7,702.

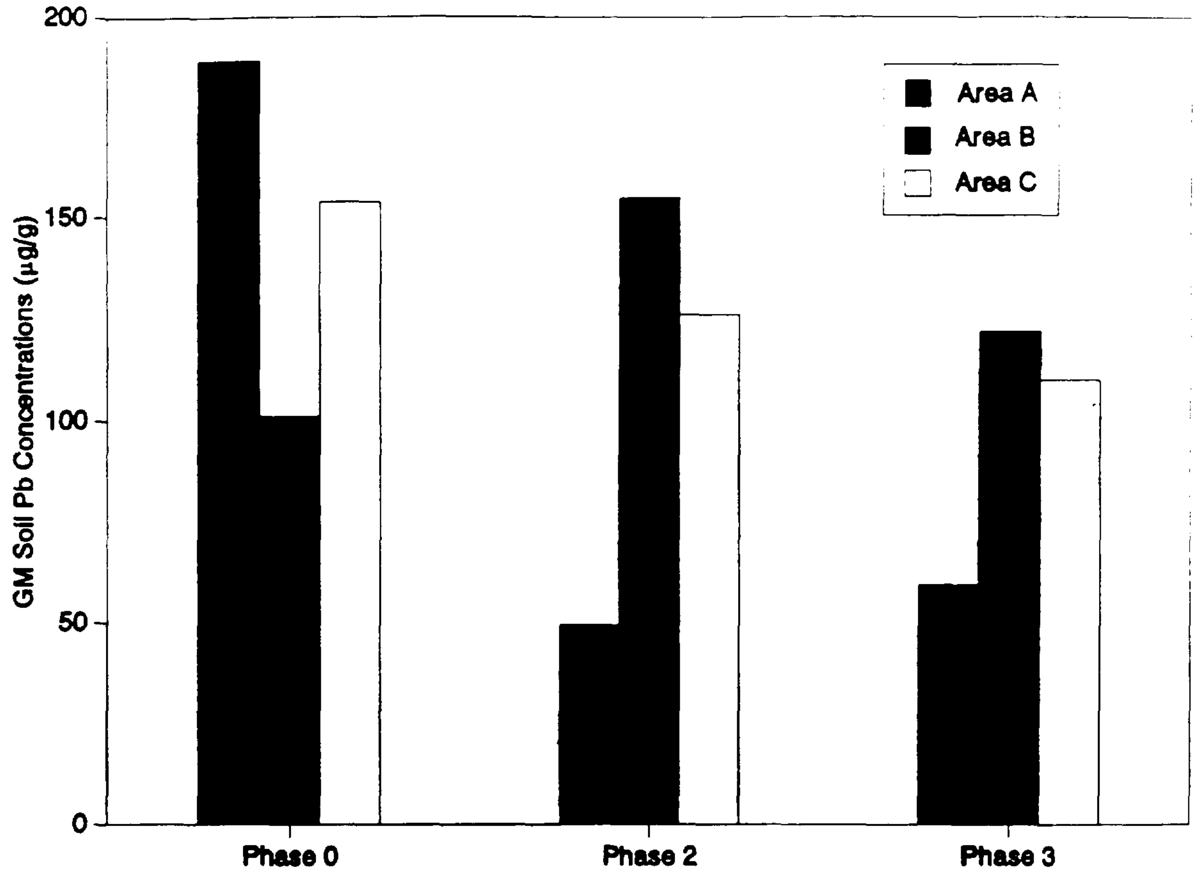


Figure 4-4. Surface scraping soil lead concentrations by Area during the preabatement (Phase 0) and early postabatement (Phases 2 and 3) periods.

Building Debris

Many of the soil areas in this demonstration project are thought to be at locations where buildings had previously been demolished. During sample collection each of the bottom 2 cm cores was visually examined to determine if building rubble could be visually observed. The presence of such evidence would support the hypothesis that building debris was used as part of the "soil" and that a building may have been located there. Soil lead concentrations may tend to be higher in such locations because of the lead-based paint that would likely be associated with some of this debris. Soil lead samples where "rubble was observed" had higher lead concentrations in Areas B and C but the difference was significant only in Area C (Table 4-22) for the pre-abatement sampling period, Phase 00. Rubble was observed in 42% of the samples in Area A, 30% in Area B and 39% in Area C.

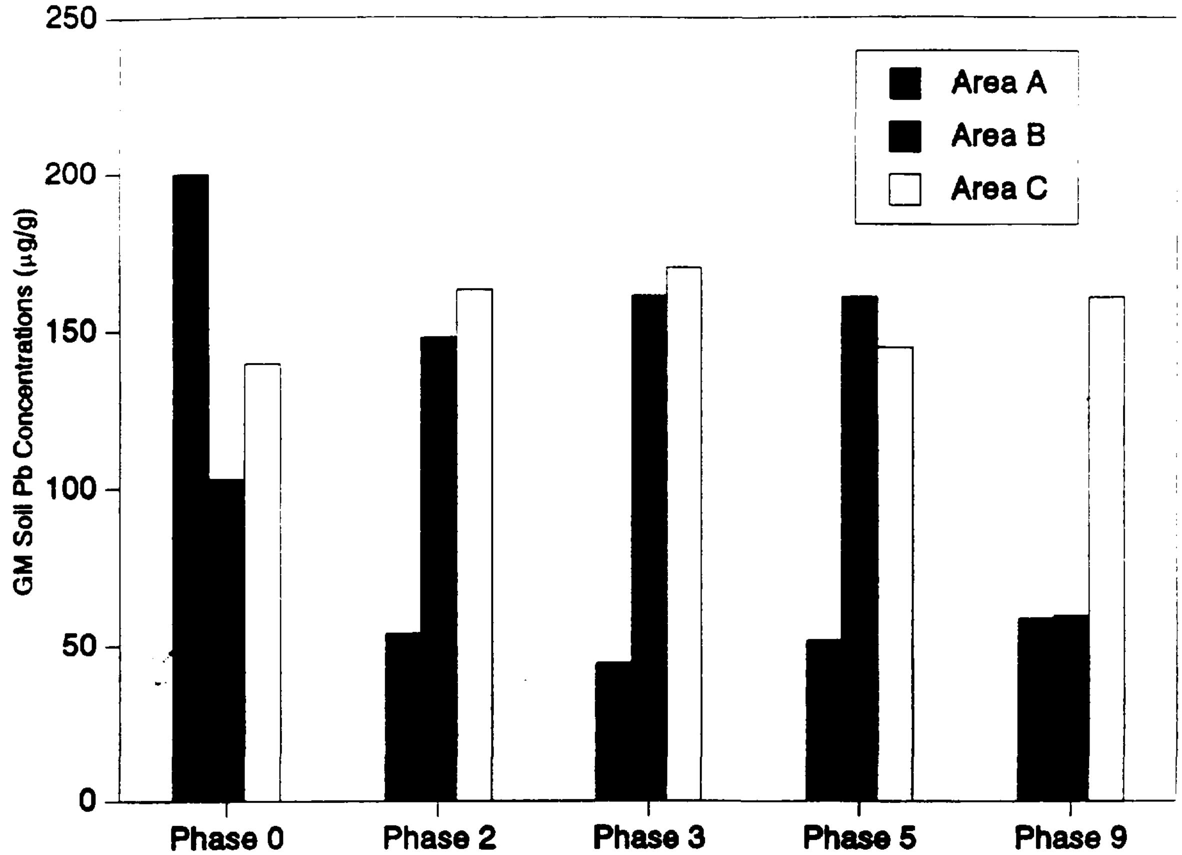


Figure 4-5. Soil lead concentrations in the top 2 cm by Area. Abatement occurred between phases 0 and 2 in Area A, and 5 and 9 in Area B.

Sampling Pattern

As described in the Methods section, four sampling patterns were utilized: line (source)-on lots adjacent to suspected sources of lead such as buildings; line (area)-in the middle of large areas; small area; and targeted areas (play areas and bare soil areas). Parcels sampled by the line (source) pattern were sampled along three parallel lines (in constrast to one for line (area) parcels).

Soil lead concentrations by sampling pattern, sample type and study area are shown for the pre-abatement sampling Phase 00 (Table 4-23). Also shown are soil lead concentrations for all patterns combined (previously shown in Table 4-21). Soil lead concentrations for line (source) sampling locations were higher than for line (area) locations for all sample types and all study areas, as hypothesized. (These differences were statistically significant except for

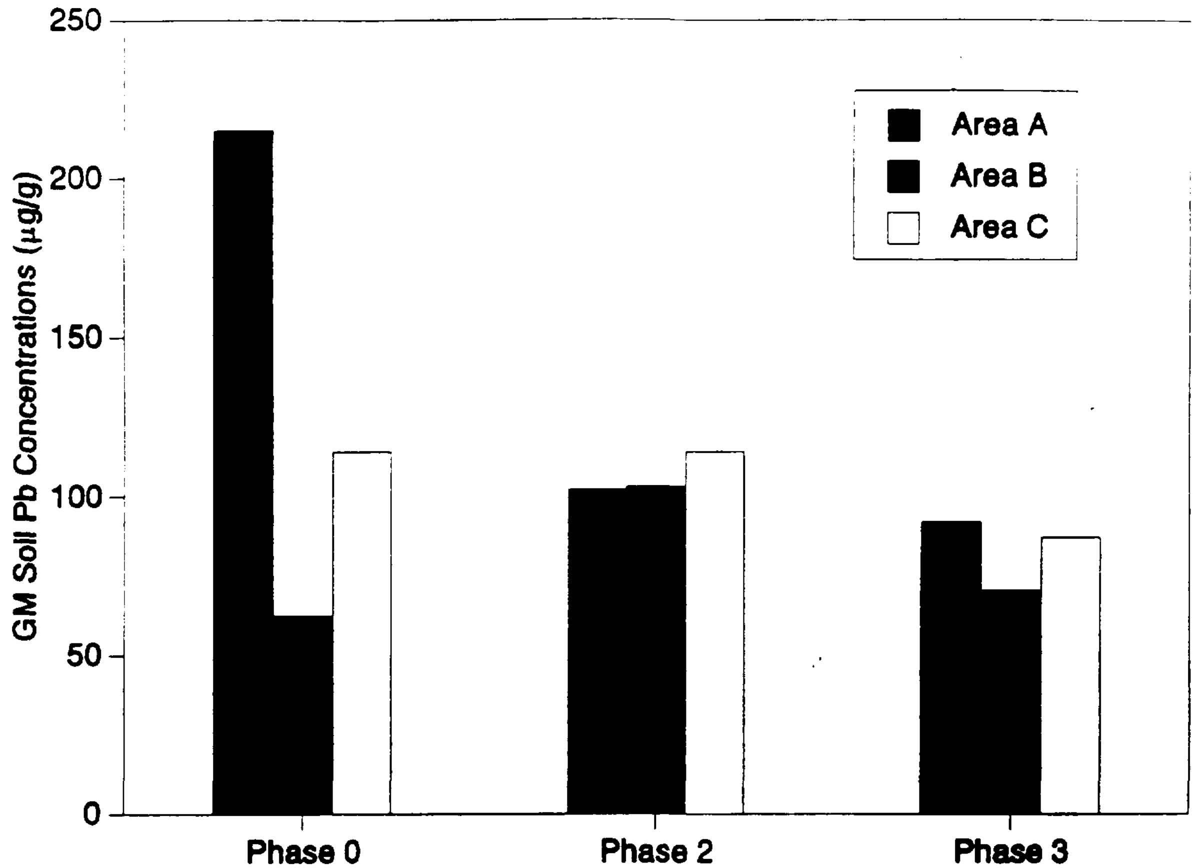


Figure 4-6. Soil lead concentrations in the bottom 2 cm of a 15 cm core, by area. Abatement of Area A was between Phase 0 and 2. Data are not available after Phase 3.

the top and bottom 2 cm samples in Area C.) For the top 2 cm samples, line (source) soil lead concentrations were 25 times higher than line (area) concentrations in Area A, 63% higher in Area B and 26% higher in Area C. Only surface scrapings were collected from "targeted" sampling areas. Soil lead concentrations for "targeted" areas were generally intermediate between those for line (source) and line (area) patterns. Soil lead concentrations for "small area" were generally the highest of the area sampling patterns for Area A where a number of these areas appeared to have existed for many years with little disturbance but were the lowest in Area C. (There was only one small area sample in Area B.)

TABLE 4-22. COMPARISON OF SOIL LEAD CONCENTRATIONS ACCORDING TO WHETHER OR NOT RUBBLE AT DEPTH WAS OBSERVED PHASE 00

	Bottom 2 cm Composite Samples from 15 cm Cores					
	Area A		Area B		Area C	
	G.M. (LCL-UCL)	95%-tile (n)	G.M. (LCL-UCL)	95%-tile (n)	G.M. (LCL-UCL)	95%-tile (n)
Rubble Observed	210 (165–267)	1,001 (81)	74 (58–95)	617 (69)	160 (126–203)	852 (84)
Rubble Not Observed	207 (153–281)	1,861 (101)	58 (51–66)	325 (161)	93 (77–112)	659 (132)

GM = geometric mean; LCL = lower confidence limit of geometric mean; UCL = upper confidence limit of geometric mean.

TABLE 4-23. COMPARISON OF SOIL LEAD CONCENTRATIONS BY SAMPLING PATTERN PHASE 00

Sampling Pattern	Area A		Area B		Area C	
	G.M. (LCL-UCL)	95%-tile (n)	G.M. (LCL-UCL)	95%-tile (n)	G.M. (LCL-UCL)	95%-tile (n)
A. Surface Scrapings						
All combined	189 (158–226)	1,996 (242)	101 (90–114)	776 (273)	154 (135–177)	1,653 (311)
Line (Source)	201 (160–254)	2,856 (153)	131 (107–159)	1,195 (122)	205 (170–247)	2,171 (176)
Line (Area)	93 (67–128)	579 (35)	82 (73–92)	216 (108)	133 (113–156)	281 (26)
Small Area	1,115 (536–2,321)	18,074 (11)	168	168 (1)	81 (51–128)	1,764 (33)
Targeted	171 (115–253)	1,570 (43)	83.0 (60–115)	626 (42)	113 (88–145)	1,500 (76)
B. Top 2 cm Core Composite Samples						
All Combined	200 (162–245)	2,659 (195)	103 (91–116)	780 (230)	140 (119–164)	1,200 (224)
Line (Source)	213 (170–268)	2,755 (150)	129 (107–156)	1,184 (122)	160 (132–194)	1,473 (166)
Line (Area)	84 (59–120)	612 (34)	79 (71–89)	192 (107)	127 (110–147)	271 (26)
Small Area	1,183 (533–2,627)	21,576 (11)	130	130 (1)	74 (48–114)	1,110 (32)
C. Bottom 2 cm Composite Samples From 15 cm Cores						
All Combined	215 (176–262)	1,612 (185)	62 (56–70)	383 (230)	114 (98–133)	848 (217)
Line (Source)	218 (176–270)	1,532 (147)	82 (68–98)	566 (122)	128 (107–154)	852 (161)
Line (Area)	111 (72–172)	617 (27)	46 (42–51)	137 (107)	77 (51–117)	592 (26)
Small Area	908 (383–2,152)	14,327 (11)	69	69 (1)	85 (62–116)	393 (30)

GM = geometric mean; LCL = lower confidence limit of geometric mean; UCL = upper confidence limit of geometric mean.
Total Number of Samples = 2,107.

4.5.1 Grass Cover

One of four categories of "grass cover" were assigned to each soil sample: fully-covered, >50% covered, <50% covered and bare. The soil lead concentrations in the surface scrapings in Phase 00 samples, presented in Table 4-24 and Figure 4-7, did not differ in any systematic way for those grass cover categories. Lead concentration in the two partially-covered categories were lower than in the bare locations in Area A; in Area C, concentrations in the locations with less than 50% grass were lower than in any of the other categories. The percent of sampling areas with >50% of the area bare, for Areas A, B and C was 55%, 57% and 75%, respectively.

4.5.2 Component Neighborhoods Within Study Areas

Areas B and C each included multiple non-contiguous neighborhood components: Findlay, Back & Dandridge for Area B and Glencoe and Mohawk for Area C. Soil lead concentrations for surface scrapings, top 2 cm cores and bottom 2 cm cores are shown in Table 4-25 for Phase 00 and 02. The Dandridge neighborhood of Area B was not added to the study until Phase 01, which did not contain soil sampling. Thus the initial soil samples for the Dandridge neighborhood were collected in Phase 02. It is unlikely that this 3-6 mo delay in sampling introduced any significant bias to the resultant data. Soil lead concentrations in the Findlay neighborhood were somewhat higher than those in the Back neighborhood while those in Dandridge were more than twice as high as either of these two for all sample depths. Concentrations in the Mohawk neighborhood were about twice as high as those in Glencoe for the surface scrapings and top 2 cm cores but only somewhat higher in the bottom 2 cm cores.

Building Debris. In the Findlay neighborhood of Area B and in the Mohawk neighborhood of Area C the geometric mean soil lead concentration in the bottom 2 cm samples were higher in samples where "rubble was observed" (Table 4-26), as was anticipated.

Grass Cover. In Area A neighborhoods lead concentrations in surface sampling were lower in locations with more than 50% grass cover than in fully-covered areas (Table 4-27). In the Dandridge neighborhood concentrations increased as the extent of grass cover

TABLE 4-24. SOIL LEAD CONCENTRATIONS IN SURFACE SCRAPINGS BY EXTENT OF GRASS COVER (ppm) (Initial Soil Samples [Phase 00])

	Area A		Area B		Area C	
Grass Cover	G.M. (LCL-UCL)	95%-tile (n)	G.M. (LCL-UCL)	95%-tile (n)	G.M. (LCL-UCL)	95%-tile (n)
Grass-Covered	240 (155–371)	1,996 (48)	135 (84–217)	1,270 (24)	193 (135–275)	2,171 (39)
>50% Grass	135 (101–182)	1,391 (61)	97 (85–111)	268 (94)	182 (131–254)	1,764 (39)
<50% Grass	123 (91–166)	1,141 (68)	96 (80–116)	705 (73)	95 (74–121)	849 (86)
Bare	340 (235–492)	3,375 (65)	103 (78–135)	1,614 (82)	185 (151-228)	1,884 (147)

GM = geometric mean; LCL = lower confidence limit of geometric mean; UCL = upper confidence limit of geometric mean; n = number of samples.

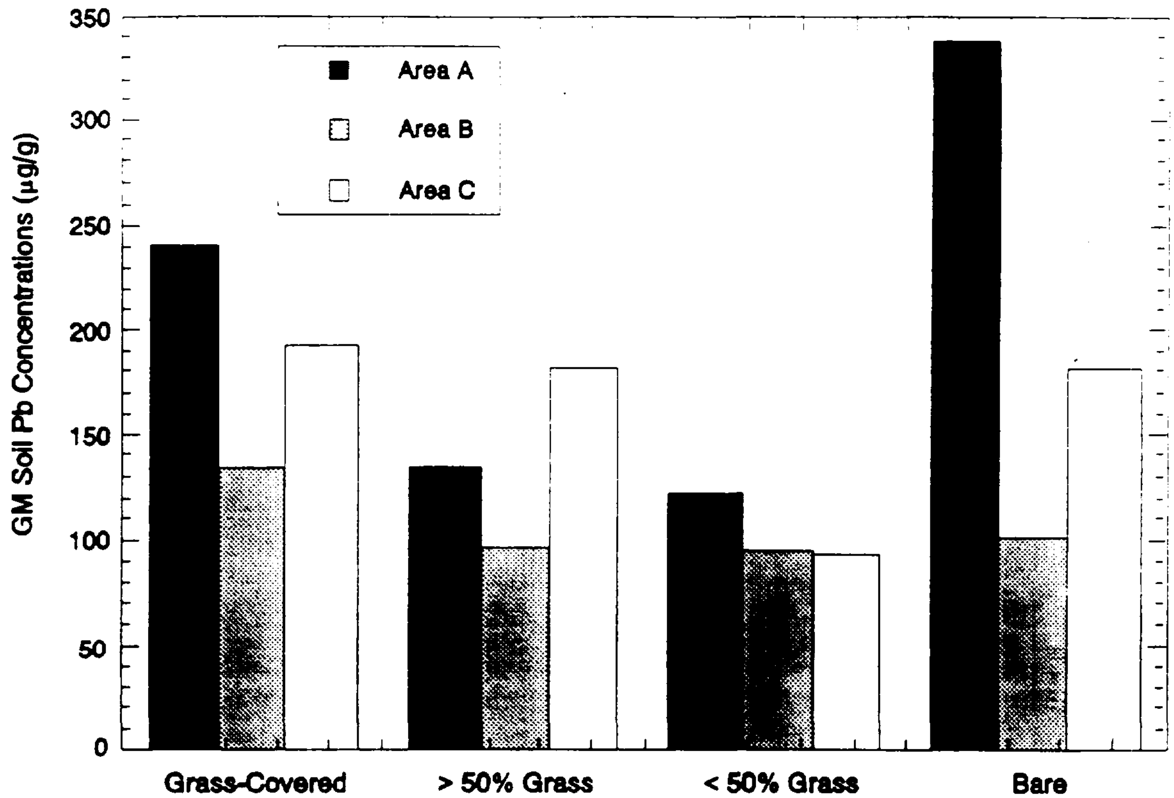


Figure 4-7. Distribution of lead concentrations by ground cover type and area, prior to abatement.

decreased. In the Glencoe neighborhood of Area C, concentrations were higher in bare location than in those with less than 50% grass-cover.

4.6 EXTERIOR DUST

Exterior dust samples were collected from several types of locations: targeted samples near entrances of study subject homes; street, sidewalk and alley samples collected throughout the study area; and samples collected from parking lots and other paved areas. Both lead concentrations (ppm) and lead loadings (μg Pb/m^2) were determined. (Only lead concentration data are available at this time.) Exterior dust samples were collected for all sample locations during Phases 1, 2, 3 and 5 but only for targeted samples for Phase 9.

TABLE 4-25. SOIL LEAD CONCENTRATIONS BY AREA COMPONENT NEIGHBORHOODS (ppm)

		Phase 00			Phase 02		
Sample/Neighborhood		G.M.	95%-tile	n	G.M.	95%-tile	n
Area B	Surface Scraping						
	Total Area	101	776	273	155	1,572	281
	Findlay	124	1,270	149	85	1,085	89
	Back	80	299	124	73	205	53
	Dandridge	not sampled	not sampled	not sampled	303	2,071	139
Area B	Top 2 cm						
	Total Area	103	780	230	148	1,192	369
	Findlay	117	1,184	132	122	1,437	134
	Back	87	256	98	93	247	103
	Dandridge	not sampled	not sampled	not sampled	257	1,617	132
Area B	Bottom 2 cm						
	Total Area	62	384	230	103	1,162	203
	Findlay	60	566	131	48	438	45
	Back	66	272	99	70	181	26
	Dandridge	not sampled	not sampled	not sampled	144	1,503	132
Area C	Surface Scraping						
	Total Area	154	1,653	311	126 (104–152)	1,759	179
	Glencoe	109	602	177	95 (79–113)	465	118
	Mohawk	244	2,547	134	218 (152–311)	2,192	61
Area C	Top 2 cm			224	163	1,347	241
	Total Area	140	1,200		(139–191)		
				128	115	804	133
	Glencoe	104	580		(96–138)		
				96	251	2,666	108
	Mohawk	206	2,547		(194–324)		
Area C	Bottom 2 cm						
	Total Area	114	848	217	114 (90–145)	1,044	89
	Glencoe	103	510	127	100 (81–123)	424	59
	Mohawk	132	1,346	90	147 (84–255)	1,677	30

Note: Soil abatement did *not* occur in areas B & C during above time periods.
GM = geometric mean.
n = number of samples.

Exterior dust lead concentrations are shown in Table 4-28 for all locations and for street, sidewalks and alleys (also shown in Figure 4-8) and in Table 4-29 and Figure 4-9 for targeted areas and for parking lots and other locations. Geometric mean concentrations in Area C are consistently about one-fifth to one-half of those in Areas A and B. For samples from "All Locations", concentrations were lower in Area A than in Area B for Phases 1, 3,

TABLE 4-26. SOIL LEAD CONCENTRATIONS (BOTTOM 2-cm SAMPLES) IN NEIGHBORHOODS BY PRESENCE OR ABSENCE OF RUBBLE OBSERVED AT DEPTH
(Initial Soil Samples [Phase 00])

Area and Neighborhood	Rubble Observed G.M. (LCL-UCL)	Rubble Observed 95%-tile (n)	Rubble Not Observed G.M. (LCL-UCL)	Rubble Not Observed 95%-tile (n)
A. Pendelton	210 (165−267)	1,001 (81)	207 (153−281)	1,861 (101)
B. Findlay	83 (55−124)	1,434 (40)	52 (44−61)	332 (91)
Back	63 (52−76)	156 (29)	68 (57−81)	325 (70)
Dandridge[*]	157 (119−206)	1,503 (83)	125 (89−175)	871 (46)
C. Glencoe	112 (82−152)	630 (34)	101 (82−123)	494 (92)
Mohawk	204 (146−283)	1,346 (50)	76 (50−117)	1,167 (40)

[*]Initial soil samples collected during Phase 02.
GM = geometric mean; UCL = lower confidence limit of geometric mean; UCL = upper confidence limit of geometric mean;
n = number of samples.

and 5 but were about the same immediately after abatement in Area A, Phase 02. For "street, sidewalk and alley" samples, concentrations in Area A and B were similar except for Phase 03 at which time they were lower in Area A. Samples from "parking lots and other locations" were lower than samples from other locations in all study areas. Lead concentrations in targeted samples were similar for Area A and B and were much lower in Area C, about 20-25% of those in Areas A and B. Exterior dust lead concentration were not expected to be altered by dust removal, since the sources of the exterior dust (e.g., from adjacent streets, sidewalks and other paved areas as well as paint chips and dust from lead-based painted houses) were not removed.

Exterior dust lead loading (mg Pb/sq. m.) data are presented for "all locations", "streets, sidewalks and alleys", "targeted locations" (at the exterior entryways of subjects' residences) and for "parking lots and other locations" in Table 4-30 and Figures 4-10 and 4-11. Data for "streets, sidewalks, and alleys" are further divided in Table 4-31 by the roadway areas ("streets", and "alleys") and by the sidewalks of each of these roadway types, called "sidewalks (streets)" and "sidewalks (alleys)". The exterior dust abatement in Area A, which occurred between Phases 01 and 02, did not produce any detectable reductions in dust

TABLE 4-27. SOIL LEAD CONCENTRATION IN SURFACE SCRAPINGS BY NEIGHBORHOOD AND BY EXTENT OF GRASS COVER (ppm) (Initial Soil Samples [Phase 00])

A. AREA B NEIGHBORHOODS

	Findlay		Back		Dandridge*	
	G.M. (LCL-UCL)	95%-tile (n)	G.M. (LCL-UCL)	95%-tile (n)	G.M. (LCL-UCL)	95%-tile (n)
Grass-Covered	257 (144–457)	1,513 (11)	78 (43–143)	937 (13)	175 (234–229)	447 (28)
>50% Grass	99 (84–117)	262 (47)	95 (77–117)	299 (47)	237 (166–338)	2,680 (46)
<50% Grass	124 (95–163)	752 (40)	71 (58–86)	273 (33)	441 (333–584)	1,933 (60)
Bare	129 (86–194)	1,738 (51)	70 (57–87)	239 (31)	696 (244–2,167)	2,975 (5)

B. AREA C NEIGHBORHOODS / C. AREA A NEIGHBORHOODS

	Glencoe		Mohawk		Pendelton	
	G.M. (LCL-UCL)	95%-tile (n)	G.M. (LCL-UCL)	95%-tile (n)	G.M. (LCL-UCL)	95%-tile (n)
Grass-Covered	78 (41–148)	147 (3)	208 (142–302)	2,171 (36)	240 (155–371)	1,996 (48)
>50% Grass	161 (103–252)	2,910 (19)	206 (126–337)	1,612 (20)	135 (101–182)	1,391 (61)
<50% Grass	73 (58–91)	395 (68)	260 (137–492)	2,749 (18)	123 (91–166)	1,141 (68)
Bare	140 (113–174)	664 (87)	278 (191–405)	3,440 (60)	340 (235–492)	3,375 (65)

*Initial soil samples collected in Phase 02.
GM = geometric mean; UCL = lower confidence limit of geometric mean; UCL = upper confidence limit of geometric mean; n = number of samples.

TABLE 4-28. EXTERIOR DUST LEAD CONCENTRATIONS (ppm)

	All Locations						Streets, Sidewalks, Alleys					
	Area A		Area B		Area C		Area A		Area B		Area C	
Phase	G.M.	(n)	G.M.	(n)	G.M.	(n)	G.M.	(n)	G.M.	(n)	G.M.	(n)
01	1,314	(217)	1,905	(304)	586	(186)	1,886	(110)	2,216	(192)	829	(98)
	(1,151–1,500)*		(1,683–2,156)		(493–697)		(1,573–2,262)		(1,919–2,559)		(658–1,045)	
	EXTERIOR ABATEMENT**											
02	1,707	(309)	1,793	(359)	529	(228)	2,154	(198)	1,794	(267)	619	(144)
	(1,530–1,905)		(1,615–1,991)		(457–612)		(1,897–2,446)		(1,582–2,034)		(504–762)	
03	928	(197)	1,658	(272)	464	(174)	1,158	(107)	1,699	(186)	634	(98)
	(792–1,090)		(1,463–1,882)		(404–536)		(946–1,418)		(1,439–2,005)		(526–768)	
05	1,312	(194)	1,970	(269)	594	(192)	2,084	(108)	1,972	(190)	816	(99)
	(1,128–1,526)		(1,744–2,226)		(501–703)		(1,733–2,507)		(1,708–2,279)		(653–1,019)	
			EXTERIOR ABATEMENT**									
06	1,184	(167)	1,954	(305)	581	(192)	1,826	(79)	2,077	(227)	667	(99)
	(1,025–1,369)		(1,745–2,188)		(490–690)		(1,493–2,232)		(1,833–2,355)		(526–846)	
07	1,255	(10)	1,888	(30)	507	(62)						
	(652–2,414)		(1,335–2,670)		(359–715)		n.a.		n.a.		n.a.	
09[a]	1,878	(10)	1,543	(31)	529	(62)						
	(1,233–2,861)		(979–2,432)		(347–748)		not sampled		not sampled		not sampled	

G.M. = geometric mean; n = number of samples; * = lower confidence limit - upper confidence limit; ** = exterior abatement - soil and exterior dust abatement; [a] = only includes targeted location samples for this phase; n.a. = not available at this time.

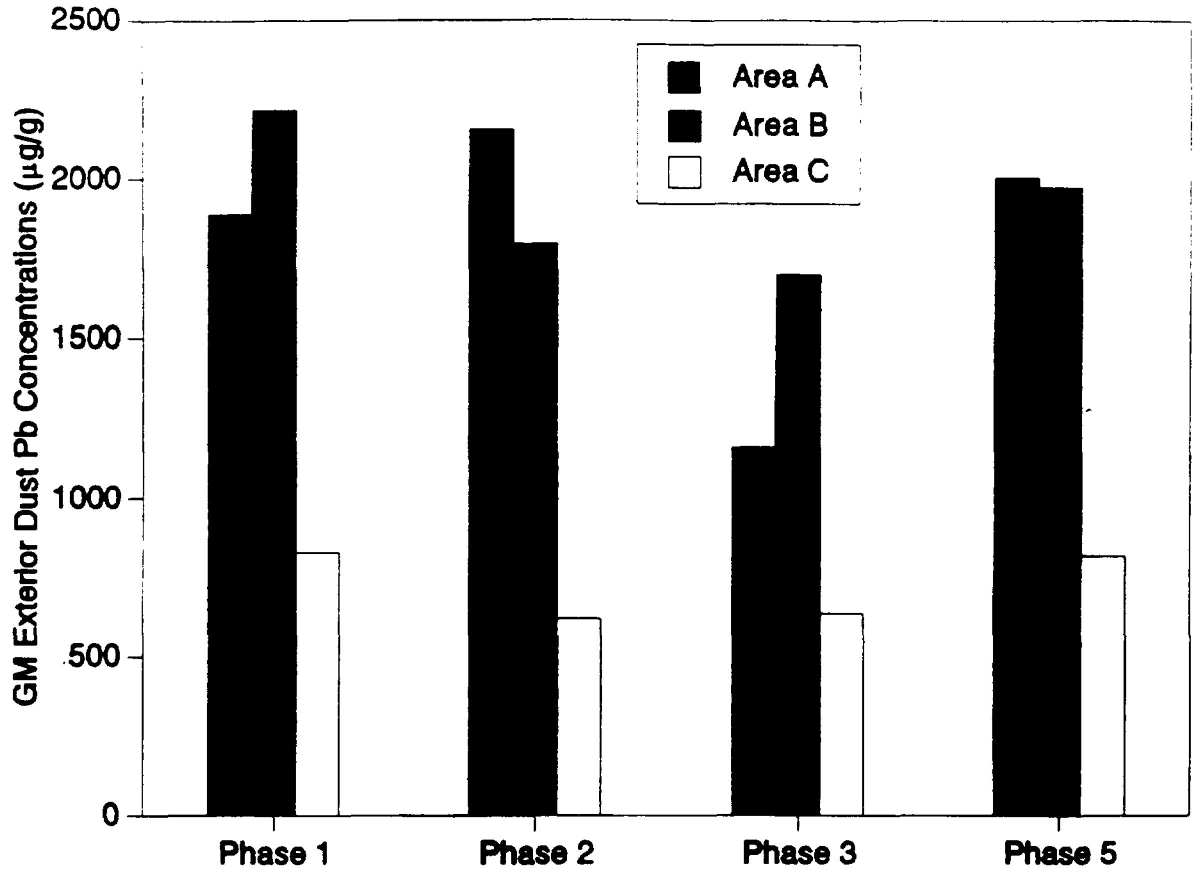


Figure 4-8. Exterior dust lead concentrations in streets, sidewalks, and alleys by area. Abatement in Area A, between Phase 1 and Phase 2 showed no apparent effect on lead concentration.

lead loadings in any of the sampling locations except the residence-targeted locations where more than a 50% reduction was observed. This reduction was not evident about 3 mo later in Phase 03 sampling. Dust lead loadings in alleys were lower post-abatement in Area A but they also were lower in Area B where no exterior dust abatement occurred at that time. Exterior *dust* loading (g dust/m^2), Table 4-32, revealed similar patterns as Table 4-30 and Figures 4-10 and 4-11.

TABLE 4-29. EXTERIOR DUST LEAD CONCENTRATIONS (ppm)

	Targeted Locations						Parking Lots and Other Locations					
	Area A		Area B		Area C		Area A		Area B		Area C	
Phase	G.M.	(n)	G.M.	(n)	G.M.	(n)	G.M.	(n)	G.M.	(n)	G.M.	(n)
01	2,148	(31)	1,791	(82)	469	(57)	637	(76)	855	(30)	293	(31)
	(1,690–2,727)*		(1,365–2,350)		(351–627)		(545–743)		(648–1,127)		(197–435)	
	EXTERIOR ABATEMENT**											
02	1,845	(17)	2,431	(63)	422	(54)	1,031	(94)	909	(29)	371	(30)
	(1,057–3,221)		(2,013–2,935)		(336–531)		(857–1,239)		(672–1,228)		(303–453)	
03	1,484	(14)	2,098	(58)	274	(45)	625	(76)	870	(28)	372	(31)
	(826–2,665)		(1,731–2,543)		(212–354)		(483–810)		(680–1,114)		(298–465)	
05	1,863	(10)	2,789	(49)	475	(62)	649	(76)	1,107	(30)	337	(31)
	(971–3,573)		(2,105–3,696)		(343–663)		(543–778)		(820–1,493)		(256–443)	
			EXTERIOR ABATEMENT**									
06	1,750	(10)	2,184	(48)	545	(62)	727	(78)	1,029	(30)	425	(31)
	(949–3,229)		(1,526–3,127)		(389–764)		(616–857)		(834–1,270)		(319–566)	
07	1,255	(10)	1,888	(30)	507	(62)						
	(652–2,414)		(1,335–2,670)		(359–715)		n.a.		n.a.		n.a.	
09[a]	1,878	(10)	1,541	(31)	529	(62)	not sampled		not sampled		not sampled	
	(1,233–2,861)		(977–2,431)		(347–747)							

G.M. = geometric mean; n = number of samples; * = lower confidence limit - upper confidence limit; ** = exterior abatement - soil and exterior dust abatement; [a] = only includes targeted location samples for this phase; n.a. = not available at this time.

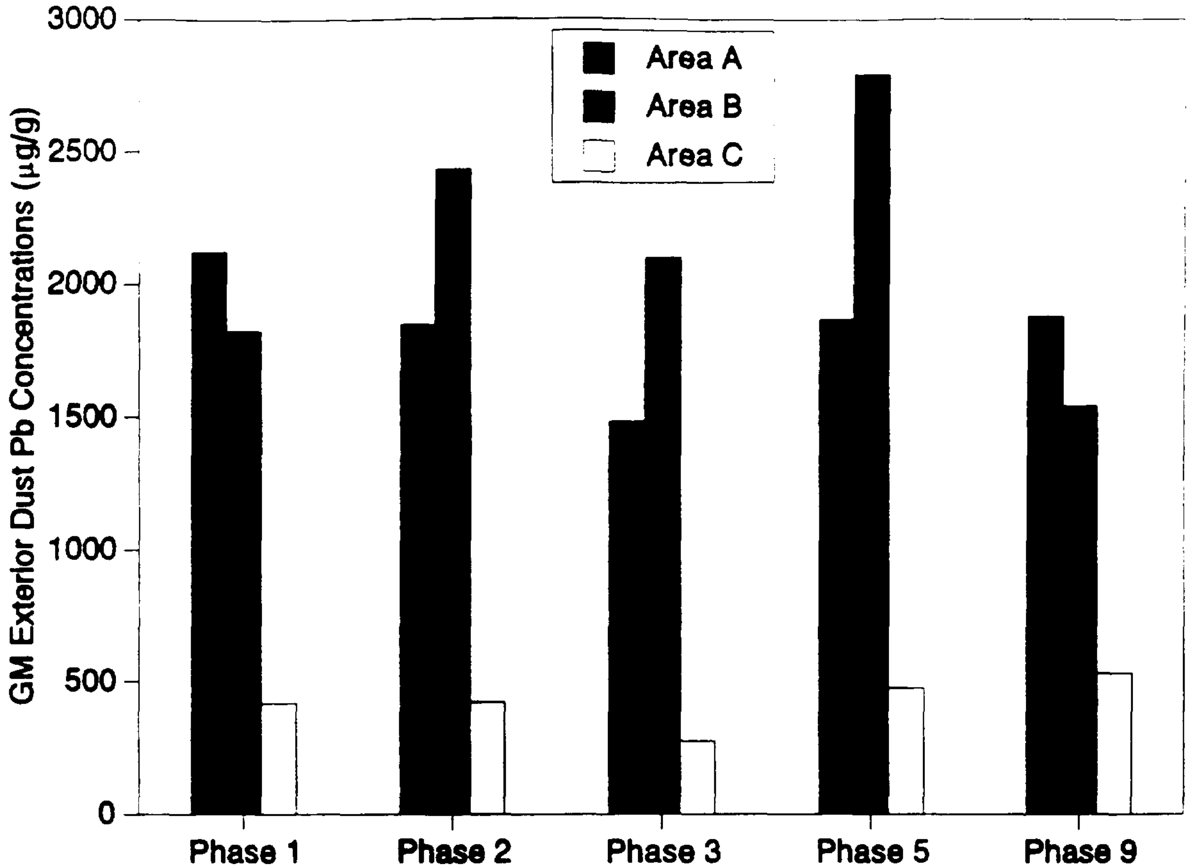


Figure 4-9. Exterior dust lead concentrations at targeted locations by area.

4.7 INTERIOR DUST LEAD

The primary locations where interior dust samples were collected are: at the interior entry, a composite of several interior floor samples, and a window sill/window well sample. Data results are expressed as both concentration (ppm) and as lead loading (μg Pb/m^2). Entry data are available for Phases 1, 2, 3, 5 and 9; and floor and window data for Phases 1, 2, 3 and 5. Dustfall and door mat data will be presented separately.

Geometric mean concentrations and loading results, along with sample size and upper and lower confidence limits of the geometric mean (for dust lead loadings) are presented in Table 4-33 for samples from the housing of initial study recruits. The sample size decreased throughout the study due to attrition. Data for entry and floor lead concentrations and loadings are also presented in Figures 4-12 and 4-13 (entry) and Figures 4-14 and 4-15 (floor).

TABLE 4-30. EXTERIOR DUST LEAD LOADING ($mg\ Pb/m^2$)

	Area A			Area B			Area C		
Phase/Location	G.M.	(n)	(LCL-UCL)	G.M.	(n)	(LCL-UCL)	G.M.	(n)	(LCL UCL)
All Locations									
01	262	(217)	(221–311)	417	(295)	(358–486)	152	(186)	(122–188)
02	245	(309)	(211–284)	405	(270)	(347–472)	161	(96)	(114–228)
03	241	(196)	(199–291)	261	(272)	(223–306)	80	(174)	(67–94)
05	299	(192)	(249–360)	312	(269)	(315–440)	117	(185)	(95–143)
Streets, Sidewalks, Alleys									
01	239	(110)	(183–311)	534	(192)	(450–634)	237	(98)	(173–324)
02	268	(198)	(220–326)	436	(242)	(369–515)	161	(96)	(114–228)
03	160	(107)	(124–207)	262	(186)	(216–317)	115	(98)	(89–147)
05	375	(108)	(293–480)	373	(190)	(306–455)	155	(99)	(117–204)
Targeted Locations									
01	241	(31)	(165–353)	241	(73)	(166–360)	95	(57)	(70–129)
02	111	(17)	(44–277)	185	(9)	(121–284)	n.a.	n.a.	n.a.
03	217	(14)	(116–406)	264	(58)	(183–381)	42	(45)	(33–54)
05	310	(9)	(157–614)	545	(49)	(368–806)	75	(55)	(50–112)
Parking Lots and Other Locations									
01	307	(76)	(236–400)	321	(30)	(228–453)	84	(31)	(53–134)
02	234	(94)	(194–284)	228	(19)	(162–321)	n.a.	n.a.	n.a.
03	429	(75)	(323–570)	236	(28)	(148–376)	62	(31)	(50–77)
05	215	(75)	(161–285)	197	(30)	(131–295)	102	(31)	(75–138)

G.M. = geometric mean; LCL = lower confidence level of geometric mean; UCL = upper confidence level of geometric mean; n = number of samples; n.a. = not available. Soil and exterior dust abatement occurred in Area A between Phases 01 and 02.

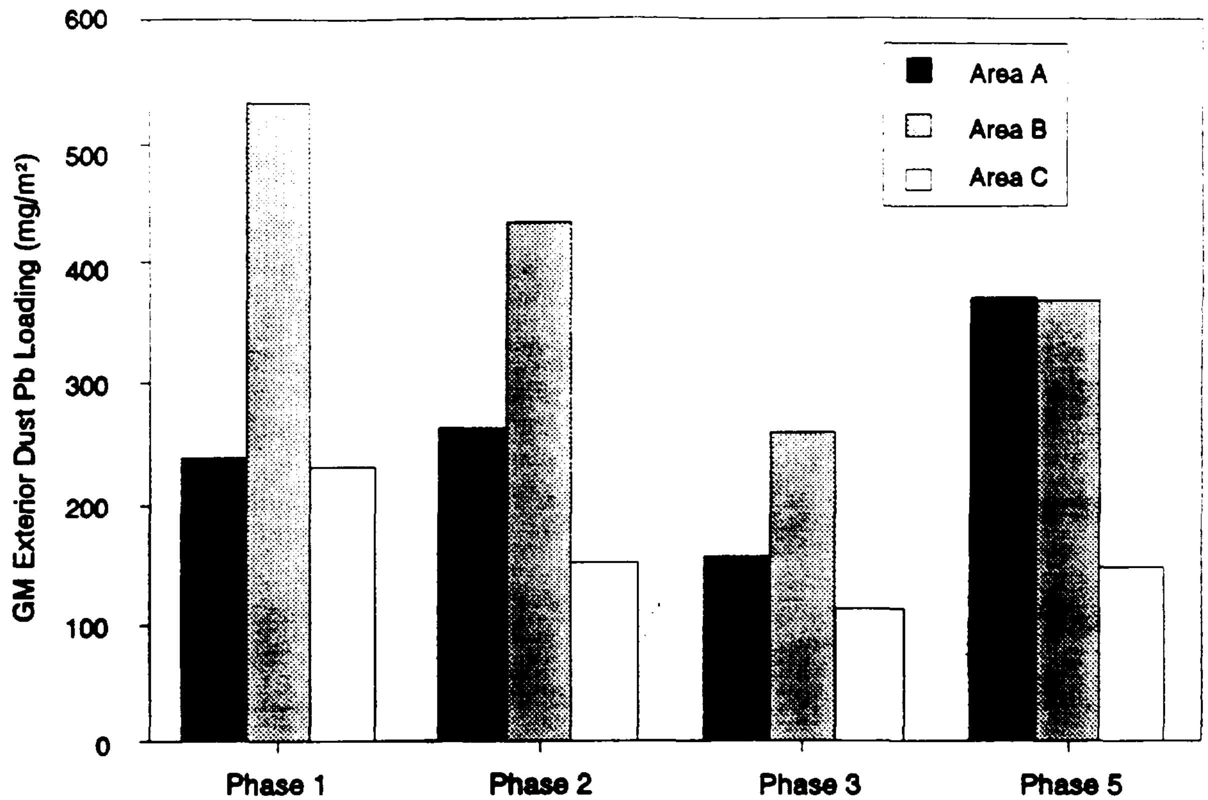


Figure 4-10. Exterior dust lead loading in streets, sidewalks, and alleys by area. Abatement in Area A, between Phase 1 and Phase 2 showed no apparent effect on lead concentration.

Interior Entry Dust. Loadings in Areas A and B decreased by 48% and 71%, respectively, between Phase 01 and 02 (pre- and post-interior and exterior abatement for Area A and pre- and post-interior abatement for Area B) compared to a reduction of 29% in Area C where no abatement occurred. The same decrease persisted in the Phase 03 sampling (Nov.-Dec. 1989) for Area A but for Area B levels increased somewhat (40% decrease from Phase 01) and were somewhat lower still for Area C (34% decrease from Phase 01). Interior entry dust lead loadings were highest in all areas during Phase 05 sampling (June-July 1990). The increase from Phase 03 was 129% in Area A, 1,164% for Area B and 242% for Area C. Interior entry loadings for Areas A and B dropped considerably between Phase 05 and Phase 09, one year later (50% and 68%, respectively) but increased for Area C (118%). Thus, it appears that the exterior abatements (soil and dust) that

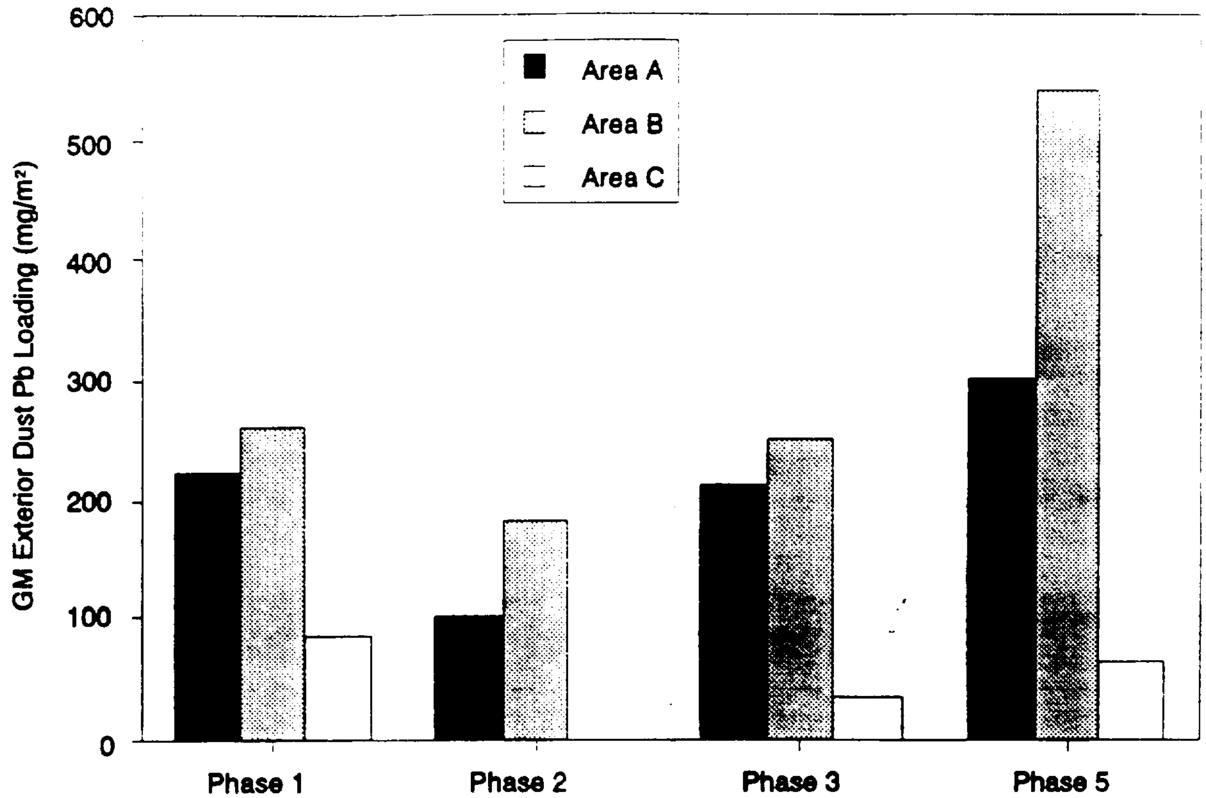


Figure 4-11. Exterior dust lead loading at targeted locations by area.

occurred in Area A and B may have had an impact on reducing annual increases in dust lead that affected Area C.

Floor Dust. Floor dust lead loadings in the Phase 01 and 02 samples followed the same general pattern as the interior entry samples with decreases from Phase 01 to 02 in Areas A and B (63% and 81%, respectively) and 19% in Area C. Loadings in Phase 03 remained less than in Phase 02 in Areas A and C but rebounded somewhat in Areas B (net reduction of 48% from Phase 01 to 02). Samples collected in Phase 05 revealed loadings in Area A that were 31% below those in Phase 012 while Areas B and C showed increases over the same period of 151% and 8%, respectively. Samples from the final sampling phase, Phase 09 (June-July 1991) showed a similar but stronger pattern for interior entry dust loadings with the geometric mean in Area A being 40% less than that in Phase 01 (two years earlier) while those in Areas B and C were 142% and 390% higher, respectively. Exterior lead abatement

TABLE 4-31. EXTERIOR DUST LEAD LOADING ($mg\ Pb/m^2$)

	Area A			Area B			Area C		
Phase/Location	G.M.	(n)	(LCL-UCL)	G.M.	(n)	(LCL-UCL)	G.M.	(n)	(LCL-UCL)
Streets									
01	152	(44)	(106–219)	390	(75)	(301–505)	213	(47)	(138–329)
02	193	(82)	(144–259)	269	(96)	(212–341)	113	(45)	(70–181)
03	131	(42)	(89–192)	214	(71)	(166–275)	91	(47)	(66–125)
05	281	(44)	(193–411)	276	(74)	(215–355)	142	(49)	(96–209)
Streets, (Sidewalks)									
01	248	(44)	(160–383)	567	(73)	(440–731)	251	(48)	(156–403)
02	328	(83)	(238–453)	693	(96)	(558–860)	205	(48)	(124–337)
03	219	(43)	(144–333)	290	(72)	(208–405)	130	(48)	(91–186)
05	459	(44)	(331–637)	447	(74)	(320–624)	155	(47)	(101–237)
Alleys									
01	1,002	(12)	(515–1,950)	1,202	(25)	(745–1,940)	778	(2)	(608–995)
02	432	(19)	(251–745)	521	(29)	(279–973)	1,442	(2)	(510–4,074)
03	164	(12)	(80–334)	309	(25)	(185–518)	1,885	(2)	(878–4,047)
05	397	(11)	(127–1,239)	538	(24)	(346–837)	591	(2)	(218–1,605)
Sidewalks (Alleys)									
01	263	(10)	(135–515)	506	(19)	(273–935)	134	(1)	
02	254	(14)	(116–556)	359	(21)	(177–727)	215	(1)	
03	104	(10)	(53–206)	330	(18)	(161–676)	100	(1)	
05	527	(9)	(208–1,331)	370	(18)	(134–1,014)	243	(1)	

G.M. = geometric mean; LCL = lower confidence level of geometric mean; UCL = upper confidence level of geometric mean; n = number of samples. Soil and exterior dust abatement occurred in Area A between Phases 01 and 02.

TABLE 4-32. EXTERIOR DUST LOADINGS
(g/m^2)

	Phase	Area A		Area B		Area C	
		(n)	G.M.	(n)	G.M.	(n)	G.M.
Streets, Sidewalks and Alleys	01	(110)	127	(192)	241	(98)	278
	02	(198)	122	(242)	250	(98)	200
	03	(108)	138	(191)	153	(99)	178
	05	(108)	178	(190)	187	(99)	188
Parking Lots and Partially Paved Parcels	01	(79)	494	(30)	376	(31)	287
	02	(122)	242	(19)	230	n.a.	n.a.
	03	(78)	719	(28)	268	(31)	165
	05	(78)	336	(30)	175	(31)	301
Residence-Targeted	01	(33)	97	(74)	133	(56)	194
	02	(39)	61	(22)	59	n.a.	n.a.
	03	(30)	169	(79)	128	(51)	155
	05	(26)	143	(68)	186	(62)	156

(soil and dust) occurred in Area B in the 2-mo period after Phase 05. Although the immediate effect of interior abatement was higher in Area B than in Area A (where both interior and exterior abatement occurred), the decrease persisted in Area A in Phase 03 (4 mo post-abatement) while there was an apparent rebound in Area B. A net decrease from Phase 01 in floor loading was even evident in Area A in the Phase 05 samples (10 mo post-abatement) while a major increase occurred in Area B and a slight one in Area C. The loadings in all post-abatement sampling phases in Area A were lower than the pre-abatement level. Non-abatement-related factor(s) apparently have major impacts on floor lead loading levels as indicated by the increases (in the Phase 05 to 09 levels in Area B).

Window Dust. Window dust loadings decreased between Phases 01 and 02 in Areas A and B by 56% and 78%, respectively, while in Area C a decrease of 26% was observed. In Phase 03 further reductions (from Phase 02) in Areas A and B of 37% and 19%, respectively occurred. In Area C, where no abatement occurred an 87% reduction was observed. For samples collected in Phase 05, very large increases occurred in all areas with loadings being 6.4, 6.4 and 4.6 times those in Phase 01 for Area A, B and C, respectively. Since these

TABLE 4-33. INTERIOR ENTRY DUST LEAD: CONCENTRATIONS AND LOADINGS (Rehabilitated Housing - Initial Recruitment Only) Geometric Mean Values

	Area A		Area B		Area C	
Phase	Concentration	Loading	Concentration	Loading	Concentration	Loading
[Entry]	340 (31)*	387 (32)*	559 (64)	245 (65)	261 (41)	150 (42)
01	(242–478)	(121–1,234)**	(437–714)	(130–464)	(184–368)	(71–313)
	INTERIOR DUST		ABATEMENT IN AREAS A & B			
02	709 (32)	230 (32)	651 (61)	56 (63)	362 (37)	105 (38)
	(537–934)	(88–599)	(542–783)	(38–83)	(261–503)	(61–179)
03	467 (31)	192 (31)	584 (60)	105 (60)	304 (36)	82 (36)
	(371–589)	(95.2–387)	(460–743)	(71–156)	(243–380)	(60–111)
05	448 (25)	439 (26)	635 (45)	1,302 (45)	346 (32)	259 (33)
	(283–710)	(169–1,137)	(488–825)	(698–2,433)	(267–448)	(115–580)
06	437 (25)	230 (25)	694 (37)	180 (37)	322 (22)	110 (22)
	(313–610)	(100–520)	(524–921)	(90–330)	(257–404)	(50–220)
07	349 (23)	60 (23)	614 (40)	130 (40)	310 (26)	70 (26)
	(266–459)	(30–100)	(475–794)	(80–210)	(225–426)	(40–130)
09	492 (18)	219 (18)	507 (32)	301 (32)	365 (22)	441 (22)
	(317–762)	(77.2–618)	(409-628)	(164-554)	(293–454)	(174–1,116)

TABLE 4-33 (cont'd). INTERIOR ENTRY DUST LEAD: CONCENTRATIONS AND LOADINGS
(Rehabilitated Housing - Initial Recruitment Only)
Geometric Mean Values

	Area A		Area B		Area C	
Phase	Concentration	Loading	Concentration	Loading	Concentration	Loading
[Floor][a]	380 (32)	188 (32)	450 (66)	138 (66)	226 (42)	46 (42)
01	(241−497)	(95−370)	(356−568)	(83−230)	(172−296)	(30−72)
	INTERIOR DUST		ABATEMENT IN AREAS A & B			
02	383 (31)	76 (32)	467 (63)	26 (63)	254 (38)	34 (38)
	(312−470)	(40−145)	(355−614)	(18−37)	(206−314)	(23.0−51)
03	363 (31)	64.3 (31)	412 (60)	53 (60)	213 (35)	32 (36)
	(289−456)	(42.7−96.9)	(358−476)	(41−69)	(181−250)	(22−45)
05	432 (26)	122 (26)	484 (46)	242 (46)	172 (32)	43 (32)
	(312−599)	(56−261)	(380−617)	(165−353)	(125−235)	(25−71)
06	383 (25)	70 (25)	379 (37)	50 (37)	228 (22)	30 (22)
	(305−481)	(40−120)	(296−487)	(30−90)	(179−290)	(20−50)

TABLE 4-33 (cont'd). INTERIOR ENTRY DUST LEAD: CONCENTRATIONS AND LOADINGS
(Rehabilitated Housing - Initial Recruitment Only)
Geometric Mean Values

	Area A		Area B		Area C	
Phase	Concentration	Loading	Concentration	Loading	Concentration	Loading
[Windows][a]	1,418 (32)	1,047 (32)	2,254 (63)	2,980 (63)	1,129 (42)	1,853 (42)
01	(998−2,014)	(420−2,613)	(1,692−3,003)	(1,584−5,607)	(799−1,596)	(927−3,699)
	INTERIOR DUST		ABATEMENT IN AREAS A & B			
02	1,282 (29)	541 (32)	1,874 (57)	592 (63)	919 (38)	1,238 (39)
	(888−1,851)	(237−1,238)	(1,350−2,601)	(322−1,085)	(629−1,341)	(506−3,029)
03	1,014 (29)	263 (29)	1,302 (60)	351 (60)	543 (35)	205 (36)
	(812−1,266)	(166−417)	(1,046−1,620)	(231−533)	(370−798)	(112−373)
05	1,957 (26)	6,084 (26)	1,908 (46)	11,714 (46)	1,220 (33)	6,724 (33)
	(1,259−3,043)	(2,239−16,529)	(1,523−2,391)	(6,746−20,340)	(894−1,664)	(2,896−15,617)
06	795 (25)	5,330 (25)	2,445 (37)	9,790 (37)	1,438 (22)	7,830 (22)
	(1,242−2,594)	(2,430−11,670)	(1,771−3,375)	(5,860−16,360)	(1,034−1,999)	(4,640−13,210)

[*] = number of samples; [**] = lower confidence limit - upper confidence limit of geometric mean; G.M. = geometric mean; n.a. = not available at this time; [a] = Phase 07 collected but not analyzed, Phase 09 not collected.

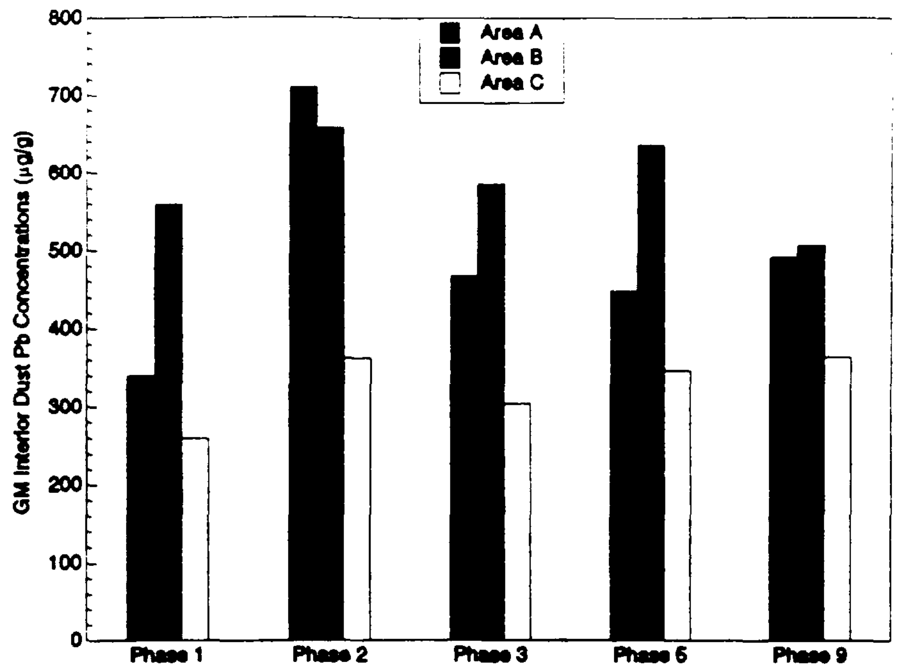


Figure 4-12. Interior dust lead concentrations at the entry way.

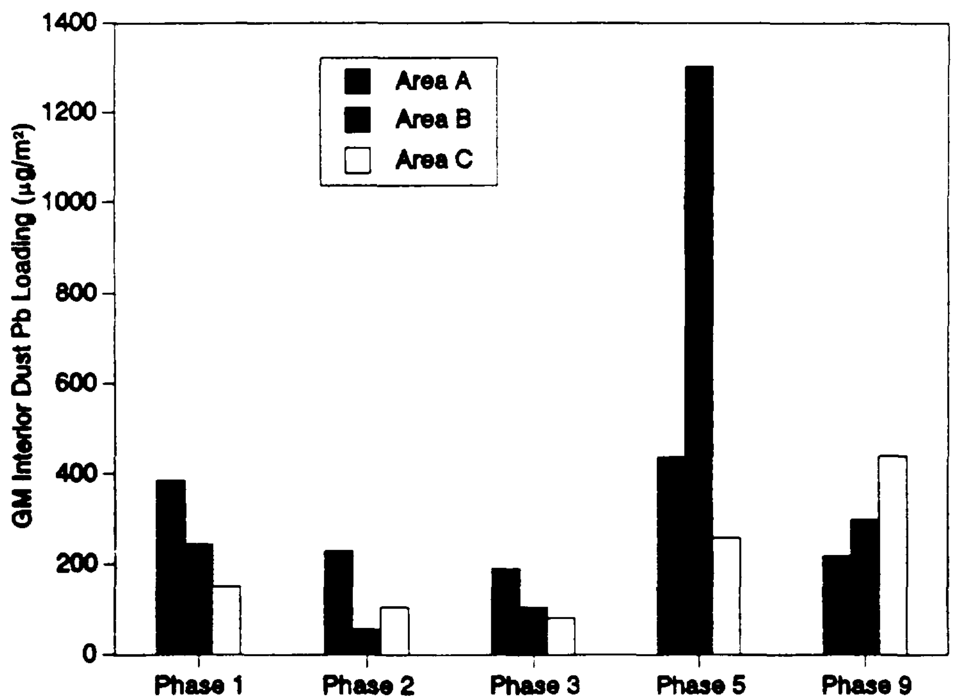


Figure 4-13. Interior dust lead loading at entryway by area. Abatement occurred in Areas A and B between Phase 1 and Phase 2.

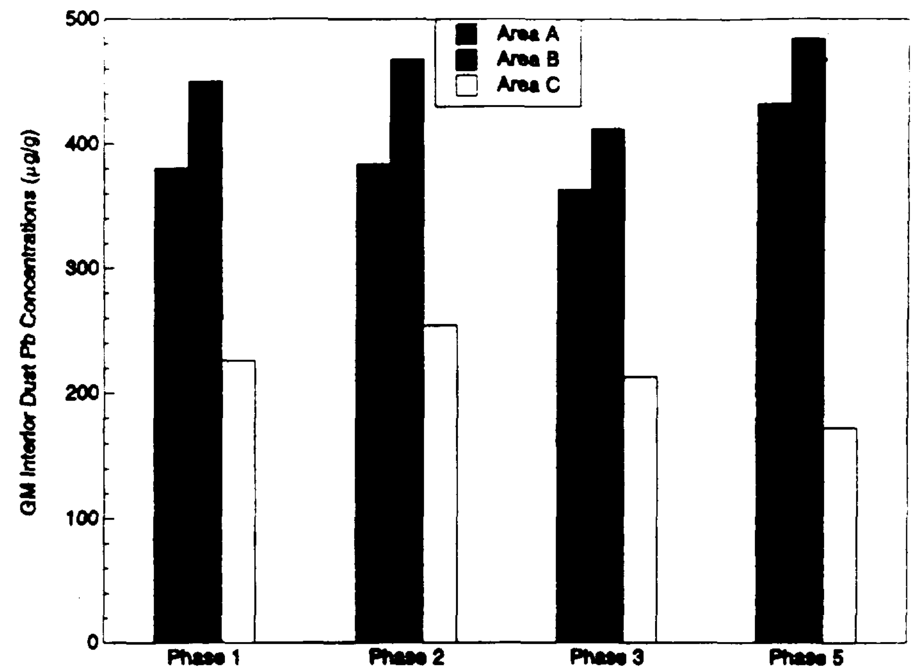


Figure 4-14. Interior dust lead concentration on the floor.

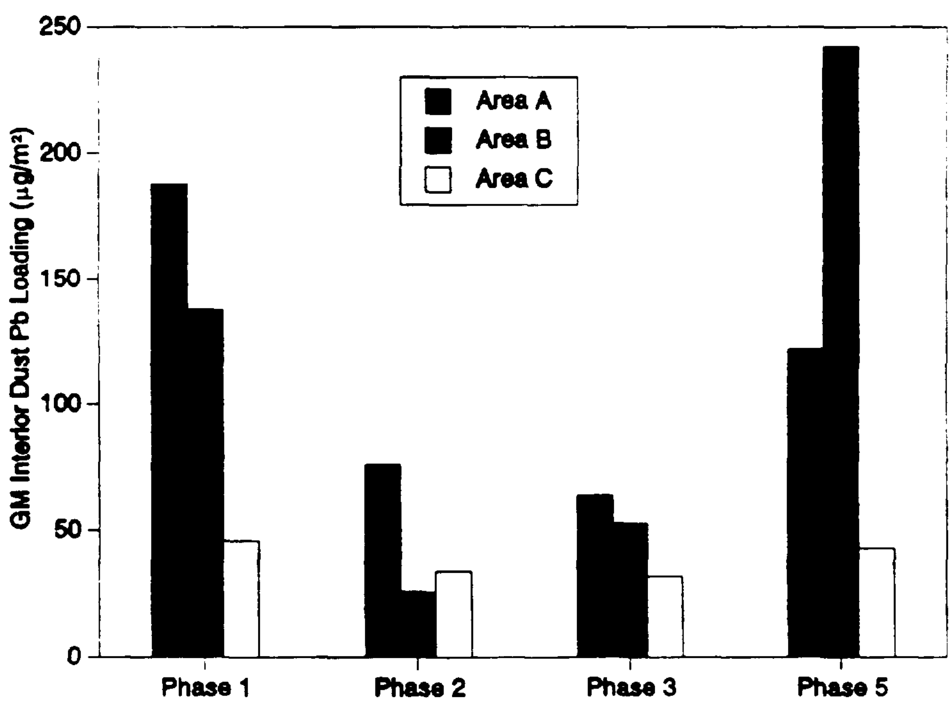


Figure 4-15. Interior dust lead loading floor by area. Abatement occurred in Areas A and B between Phase 1 and Phase 2.

increases occurred in all areas they are not associated with abatement and are evidently due to annual variation or yet unidentified other factor.

Door Mat Dust. A total of four door mats were placed inside the entry of the subjects' homes during the study. Doormats were placed in the homes during the abatement periods, 1989 and 1990, to detect any build-up of lead that might result from abatement. Other doormats were placed in the homes after these abatement periods and left until the preabatement sampling period the next year. A summary of doormats placed in the homes, when they were removed, which mat was sampled during a particular sampling phase and approximately how long the sampled mat had been in the home are summarized in Appendix K.

Reduced Data Set. In order to examine changes between phases for the *same set of housing*, a reduced set of the data was analyzed. For a given pair of sampling phases, say 01 and 02, only the data from housing sampled in both phases was used. Interior entry dust lead values (concentrations and loadings) are presented in Table 4-34 (and Figures 4-16 to 4-19), interior floor dust in Table 4-35 and Figures 4-20 and 4-21 (Area A) and Figures 4-22 and 4-23 (all areas) and interior window dust in Table 4-36. Patterns of change are similar to those noted in the total data set but some differences are evident. Interior dust loading decreases were still observed in Area A and B between Phases 01 and 02 and between 01 and 03. For a comparison of Phases 01 and 05 samples and 01 and 09 samples,loadings were slightly lower in the later phase samples for Area A but were much higher for Areas B and C. This pattern of changes may be due to overall annual increases which are meliorated by the simultaneous interior and exterior abatement activities in Area A.

Interior floor lead loading reductions coinciding with abatement were evident in Area A and appeared to persist through Phase 05, some 10 mo post abatement (Table 4-35). A decline in Area B was only evident through Phase 03, 3 mo post-abatement; and in Area C little change in loadings were observed.

Window dust lead loadings followed the same pattern as for the whole data set with large increases between Phases 01 and 05 in all areas and a large reduction in Area C between Phase 01 and 03.

TABLE 4-34. INTERIOR ENTRY DUST LEAD (PAIRED DATA)
(Rehabilitated Housing - Initial Recruits)
Geometric Mean Values (ppm)

Phase	Area A		Area B		Area C	
	Concentration	Loading	Concentration	Loading	Concentration	Loading
01	323 (27)* (221–472)	462 (28)** (125–1,708)***	547 (58) (421–711)	242 (61) (125–470)	278 (35) (192–403)	137 (37) (66–283)
02	757 (27) (552–1,038)	279 (28) (98–794)	614 (58) (517–729)	54 (61) (37–79)	360 (35) (255–508)	108 (37) (62–187)
01	316 (26) (218–459)	445 (27) (116–1,697)	511 (57) (400–654)	175 (58) (102–299)	231 (34) (168–318)	112 (35) (57–218)
03	475 (26) (363–621)	216 (27) (100–465)	574 (57) (446–737)	101 (58) (69–149)	295 (34) (234–371)	80 (35) (59–110)
01	310 (22) (200–481)	478 (23) (109–2,097)	441 (22) (350–557)	164 (42) (86–311)	236 (28) (161–346)	127 (30) (62–259)
05	441 (22) (264–734)	462 (23) (172–1,238)	610 (42) (467–797)	1,413 (42) (734–2,719)	337 (28) (259–440)	206 (30) (97–439)
01	351 (15) (244–506)	209 (15) (38–1,154)	430 (29) (321–577)	186 (29) (83–419)	215 (17) (122–378)	119 (18) (52–272)
09	591 (15) (371–942)	260 (15) (92–734)	515 (29) (411–645)	319 (29) (164–620)	324 (17) (255–410)	367 (18) (139–967)

Concentration = geometric mean lead concentration ppm; loading = geometric mean lead loading µg Pb/sq.m.; * = for each pair of phases compared, only data from households represented in both phases was used; ** = number of samples; *** = upper and lower confidence limits of geometric mean. Interior dust abatement occurred in Areas A and B between Phases 01 and 02.

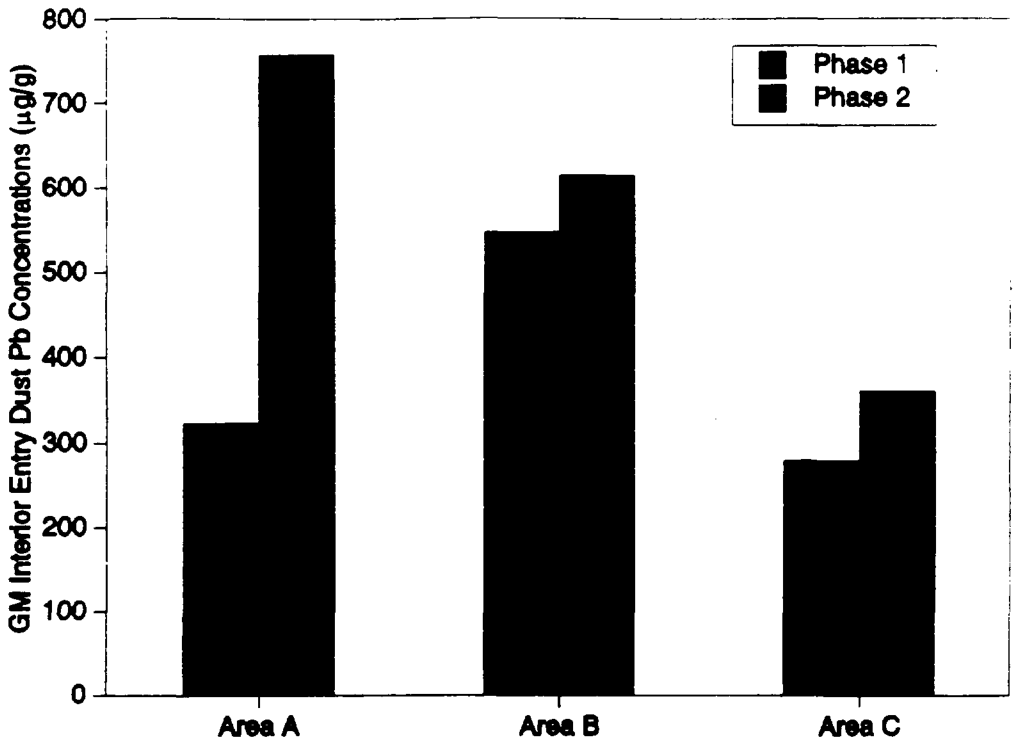


Figure 4-16. Comparison of interior entryway dust lead concentrations between Phases 1 and 2. Dust abatement occurred between Phases 1 and 2 in Areas A and B.

Changes in geometric mean interior dust lead loading changes are summarized in Table 4-37. Changes are also expressed adjusting for the changes observed in the control area (C) (Table 4-38).

Interior dust loadings (mg dust/m^2), Tables 4-39 and 4-40, show similar patterns for dust lead loadings. About 10 mo after abatement, floor dust loadings in Area A were still 43% below preabatement levels while in Area B they were 65% higher than preabatement levels.

4.7.1 Net Change in Lead Loading

Entry Dust

For the entry dust loading (Table 4-34) there is a significant reduction between Phases 01 and 02 (before and after abatement) in both Areas A and B (where abatement occurred) and an insignificant decrease in control Area C where no abatement occurred.

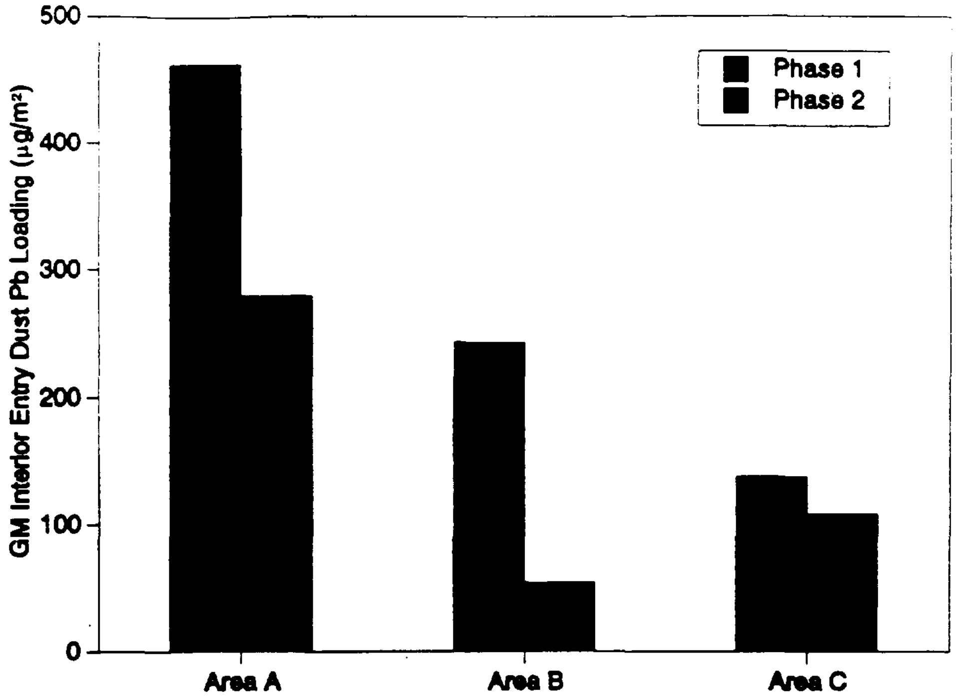


Figure 4-17. Comparison of interior entryway dust lead loading between Phases 1 and 2. Dust abatement occurred between Phases 1 and 2 in Areas A and B.

Comparing Phases 01 and 03 (before abatement and about 3 mo post-abatement) loadings are about 50% lower in Phase 3 than in Phase 1 for Areas A and B but the confidence intervals overlap. Comparing Phases 01 and 05, Area A showed no differences but Phase 05 levels were almost as high in Area B and more than 2X as high in Area C. Evidently conditions across study areas, independent of abatement, occurred to increase dust lead loadings. Either these conditions did not reach Area A (doubtful since it is adjacent to part of Area B and within one-half mile of other areas) or the exterior abatement that occurred along with interior abatement in Area A reduced its impacts.

Comparing entry dust loading results for Phase 09 with those for Phase 01 revealed loadings about 10% higher in Area A, over twice as high in Area B and 3.5 times as high in Area C.

Floor dust loadings (Table 4-35) decreased between phases 01 and 02 for both Area A and B by about 60% and 80%, respectively, but less than 5% in Area C where no interior

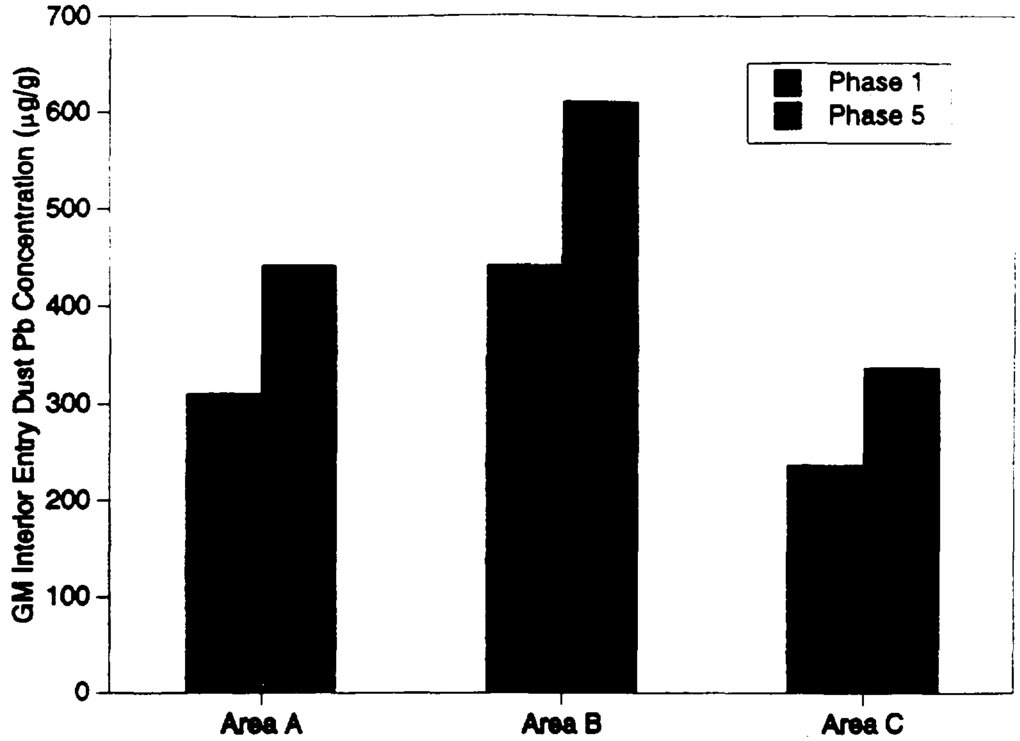


Figure 4-18. Comparison of interior entryway dust lead concentrations between Phases 1 and 5. Dust abatement occurred between Phases 1 and 2 in Areas A and B.

abatement occurred. For Area A the reduction was about the same for Phase 01 to 03 but for Area B it was less than 50%. When comparing Phase 05 results with those from Phase 01, loadings were almost 40% lower in Area A, but had increased more than 2-fold in Area B and by about 10% in Area C.

Window Loadings

Results for window lead loadings (Table 4-36) revealed that significant decreases from Phase 01 to Phase 02 in Areas A and B indicating an apparent abatement effect. Comparing Phases 01 and 03 revealed significant *decreases* in *all* areas. Comparing results from Phase 01 and 05 revealed large *increases* (3-6-fold) in *all* areas. Evidently, events independent of abatement had a major impact on window dust loadings. Geometric mean window dust concentrations exhibited only relatively minor variations.

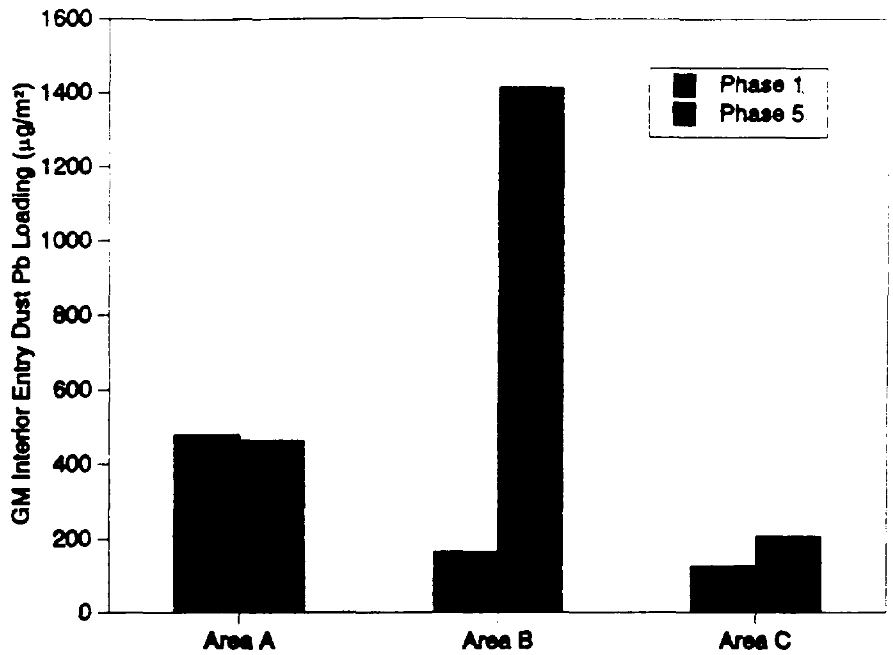


Figure 4-19. Comparison of interior entryway dust lead loading between Phases 1 and 5. Dust abatement occurred between Phases 1 and 2 in Areas A and B.

Percent changes in window dust, entry and floor dust lead loadings between phases for the matched sets of housing are shown in Table 4-37. If factors involved in changes occurring in control Area C are assumed to be operative in Area A and B, then an adjustment in changes in Areas A and B may be able to be made to estimate the "net abatement effect". Results shown in parenthesis in Table 4-37 are one attempt at such adjustment. If such adjustments are valid, an abatement impact may exist up through the end of the study.

4.8 BLOOD LEAD

Blood lead concentrations for the initial recruits is shown for the three study areas and for the five blood collection phases in Table 4-41. The geometric mean ranged from 8.02 to 10.45 in Phase 01 prior to abatement. For most of the study the geometric mean PbB was lower in Area C (the control area) than in the two other areas. However, results from the last blood collection revealed that concentrations in all three areas were almost identical.

TABLE 4-35. INTERIOR FLOOR DUST LEAD (PAIRED DATA)
(Rehabilitated Housing - Initial Recruits)
Geometric Mean Values (ppm for Concentration and $\mu gPb/m^2$ for Loading)

	Area A		Area B		Area C	
Phase*	Concentration	Loading	Concentration	Loading	Concentration	Loading
01	375 (27)*	220 (28)**	446 (62)	139 (62)	218 (37)	40 (37)
	(275–512)	(104–467)***	(348–571)	(81–238)	(162–294)	(25–63)
02	388 (27)	87 (28)	463 (62)	25 (62)	256 (37)	35 (37)
	(307–491)	(43–176)	(350–612)	(17–36)	(206–317)	(23–52)
01	370 (27)	222 (27)	416 (59)	114 (59)	205 (34)	37 (35)
	(285–479)	(105–469)	(326–531)	(71–185)	(154–274)	(24–58)
03	361 (27)	66 (27)	417 (59)	53 (59)	212 (34)	31 (35)
	(278–469)	(41–104)	(361–481)	(41–69)	(179–250)	(22–45)
01	395 (22)	246 (22)	361 (43)	122 (43)	201 (29)	39 (29)
	(289–539)	(105–578)	(295–443)	(71–209)	(145–279)	(24–61)
05	509 (22)	154 (22)	446 (43)	248 (43)	166 (29)	37 (29)
	(377–689)	(70–335)	(384–642)	(166–370)	(117–234)	(22–62)

Concentration = geometric mean lead concentration ppm; loading = geometric mean lead loading μg Pb/sq.m.; * = for each pair of phases compared, only data from households represented in both phases was used; ** = number of samples; *** = upper and lower confidence limits of geometric mean. Interior dust abatement occurred in Areas A and B between Phases 01 and 02.

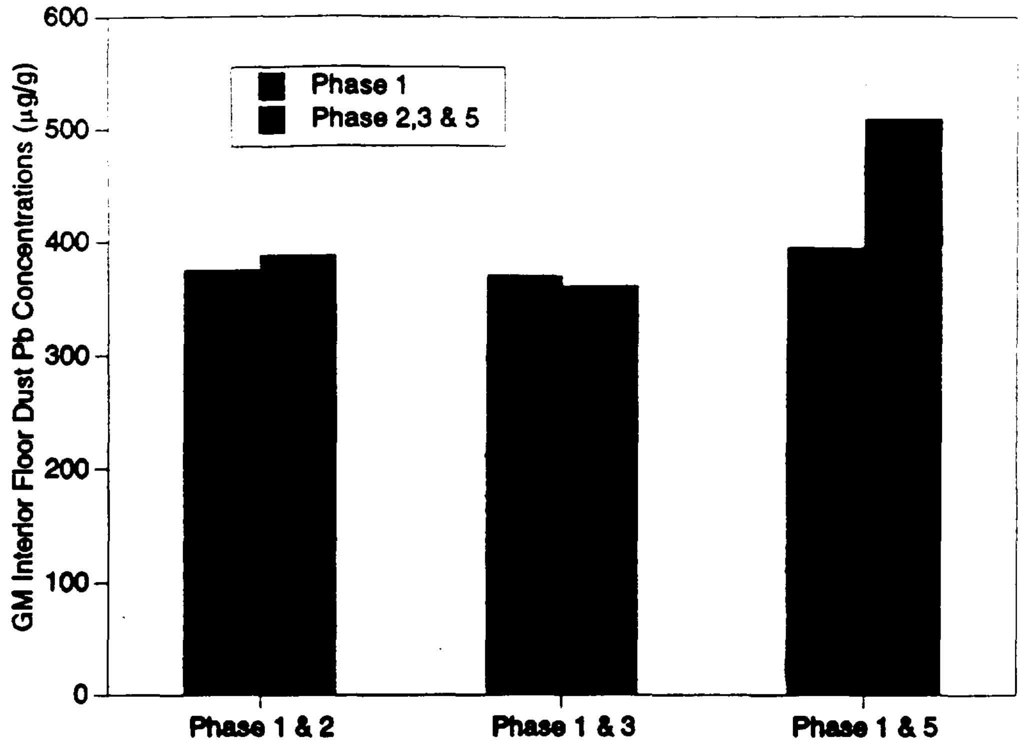


Figure 4-20. Pre- and postabatement interior floor dust lead concentrations in Area A.

A comparison of blood lead levels between phases, using only data available from the same children in both phases (Table 4-42) reveals the same patterns as for the larger data set show in Table 4-41.

The geometric mean of the blood lead ratios between phases (Table 4-43) reveals that geometric mean of the ratio of Phase 03 blood lead level to Phase 01 blood lead was lower in Area C (where no abatement occurred) than in Area B (interior abatement). Thus, blood lead levels dropped more in Area C. The geometric mean of the ratio in Area A was slightly lower in Area A than in Area B.

The mean decrease in blood lead level between phases (Table 4-43) revealed that the decrease in Area C was 0.69 $\mu g/dL$ more than that in Areas A and B. Between Phases 01 and 09, blood lead levels decreased by 2.09 in Area B and 1.30 in Area C compared to an increase in Area A. The difference between Areas A and B was statistically significant. Since the subjects compared in Table 4-43 were active in the study in both phases comparisons based on Table 4-43 should be given more weight than those from the data in Table 4-41 which includes subjects in earlier phases who are not represented in later phases.

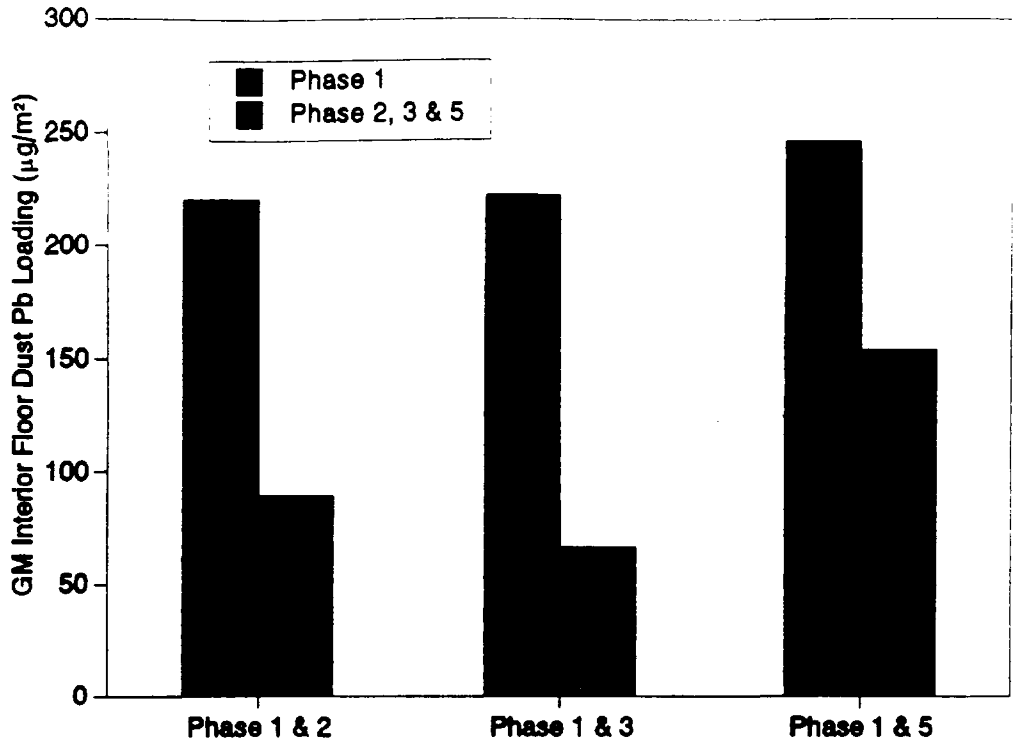


Figure 4-21. Pre- and postabatement interior floor dust lead loading in Area A.

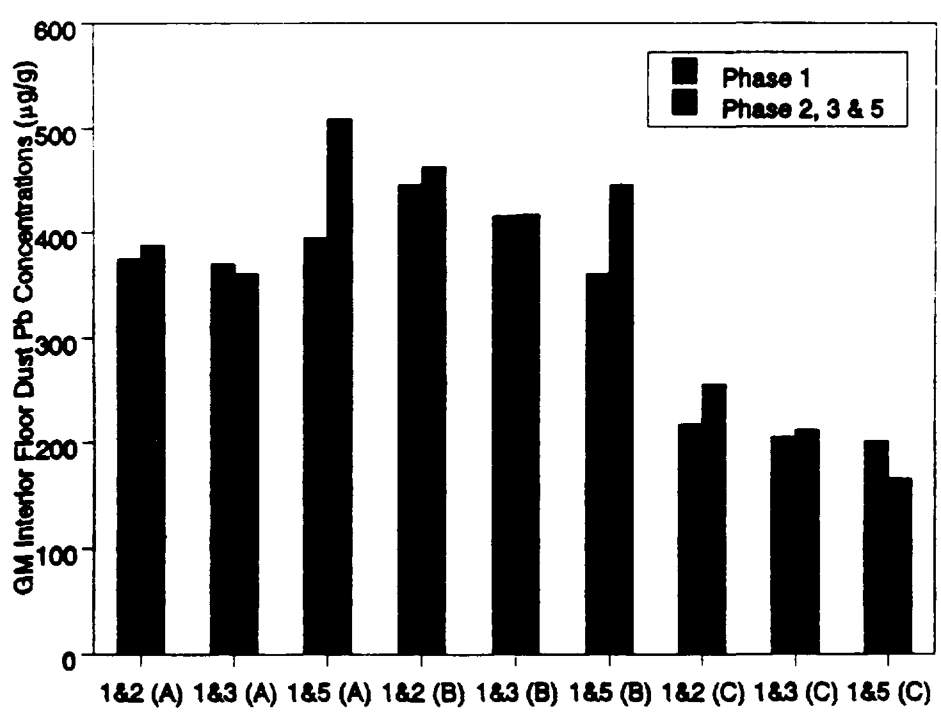


Figure 4-22. Pre- and postabatement floor dust lead concentrations, all areas.

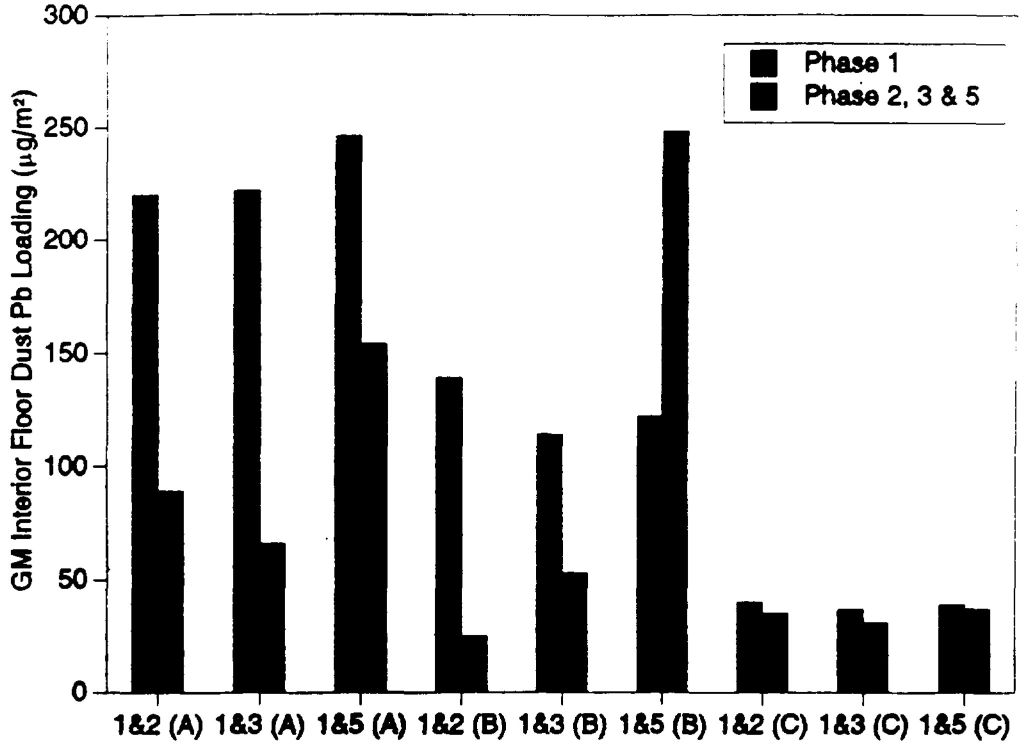


Figure 4-23. Pre- and postabatement floor dust lead loading, all areas.

Age. The preabatement (Phase 01) blood lead levels of the children in the study was highest for children between two and three years of age (Table 4-44 and Figure 4-24) and tended to level off at about 8 μg/dL at older ages. For children living in non-rehabilitated housing, the peak, although higher by a geometric mean of 11 μg/dL, was also between 2 and 3 years of age. The ratio of blood lead levels of Phase 05 to Phase 01, and of Phase 09 to 01, are shown in Table 4-45 and Figures 4-25 and 4-26. For children at least one and less than three years old at Phase 01, geometric mean blood lead levels were less at Phase 05 for all three study areas.

4.9 HAND LEAD

Hand lead values by study group and study phase are presented in Table 4-46. Prior to any abatement activity (Phase 01) hand lead values were lower in Area C than in either Areas A or B with only the difference between Areas A and C being statistically significant.

TABLE 4-36. INTERIOR WINDOW DUST LEAD (PAIRED DATA)
(Rehabilitated Housing - Initial Recruits)
Geometric Mean Values (ppm)

	Area A		Area B		Area C	
Phase[*]	Concentration	Loading	Concentration	Loading	Concentration	Loading
01	1,404 (25)[*]	1,360 (28)[**]	2,281 (53)	2,933 (59)	1,167 (37)	1,910 (38)
	(942–2,093)	(513–3,608)[***]	(1,649–3,155)	(1,506–5,714)	(797–1,708)	(910–4,005)
02	1,263 (25)	618 (28)	1,812 (53)	487 (59)	917 (37)	1,338 (38)
	(825–1,933)	(249–1,535)	(1,279–2,569)	(270–877)	(622–1,354)	(541–3,309)
01	1,301 (25)	1,329 (25)	2,165 (57)	2,453 (57)	1,038 (34)	1,550 (35)
	(901–1,879)	(481–3,668)	(1,590–2,946)	(1,274–4,724)	(719–1,499)	(742–3,236)
03	1,076 (25)	289 (25)	1,284 (57)	349 (57)	531 (34)	202 (35)
	(849–1,363)	(177–471)	(1,021–1,615)	(226–541)	(359–787)	(109–373)
01	1,547 (22)	2,074 (22)	1,681 (42)	2,099 (42)	1,168 (30)	2,082 (30)
	(1,096–2,183)	(709–6,065)	(1,184–2,388)	(939–4,689)	(796–1,715)	(933–4,647)
05	2,242 (22)	6,791 (22)	1,835 (42)	13,300 (42)	1,261 (30)	7,491 (30)
	(1,437–3,498)	(2,197–20,990)	(1,478–2,277)	(7,661–23,087)	(924–1,722)	(3,222–17,420)

Concentration = geometric mean lead concentration ppm; loading = geometric mean lead loading µg Pb/sq.m.; * = for each pair of phases compared; only data from households represented in both phases was used; ** = number of samples; *** = upper and lower confidence limits of geometric mean. Interior dust abatement occurred in Areas A and B between Phases 01 and 02.

TABLE 4-37. PERCENT REDUCTION BETWEEN PHASES IN GEOMETRIC MEAN INTERIOR DUST LEAD LOADINGS (PAIRED DATA)

	Area A			Area B			Area C		
Phases	Entry	Floor	Window	Entry	Floor	Window	Entry	Floor	Window
01 - 02	-40 (-18)*	-61 (-47)	-55 (-25)	-78 (-56)	-82 (-68)	-83 (-53)	-22 (0)	-14 (0)	-30 (0)
01 - 03	-51 (-23)	-70 (-54)	-78 (+9)	-42 (-14)	-54 (-38)	-86 (+1)	-28 (0)	-16 (0)	-87 (0)
01 - 05	-3 (-66)	-38 (-32)	+227 (-32)	+763 (+701)	+104 (+109)	+534 (+274)	+62 (0)	-5 (0)	+260 (0)
01 - 09	+24 (-184)	(no samples)	(no samples)	+71 (-136)	(no samples)	(no samples)	+208 (0)	(no samples)	(no samples)

Only data available from the same housing in both sampling phases pairs are compared.
*Percentages in parentheses represent changes relative to Area C where no abatement occurred (change in Area C thus becomes zero).
Interior dust abatement occurred in Areas A and B between Phases 01 and 02.

TABLE 4-38. CHANGES IN INTERIOR DUST LEAD LOADINGS BETWEEN SAMPLE COLLECTION TIMES

	Interior Entry Area		
	Area A	Area B	Area C
Phase 01 ⟶ 02*	(Pre/Post Interior/Exterior Abatement)	(Pre/Post Interior Abatement)	No Abatement
	49% Reduction	73% Reduction**	12% Reduction
Phase 01 ⟶ 03	Pre-Abatement to 3 mo Post Abatement (Interior/Exterior)	Pre-Abatement to 3 mo Post Interior Abatement	No Abatement (June and November Approximate Sampling Times)
	53% Reduction	45% Reduction	18% Reduction
Phase 01 ⟶ 05	6% Reduction	687% Reduction	126% Reduction
Phase 01 ⟶ 09	21% Reduction (231%)	112% Reduction (140%)	252% Reduction (0)

*Only data available at both sampling in same housing units, times was used.
**$P < 0.05$.

TABLE 4-39. INTERIOR DUST LOADINGS (mg dust/m^2)

	Phase	Area A G.M.	Area A (n)	Area B G.M.	Area B (n)	Area C G.M.	Area C (n)
Entry	01	1,240	(32)	440	(64)	610	(41)
	02	340	(33)	90	(64)	380	(39)
	03	410	(31)	180	(60)	270	(36)
	05	1,130	(25)	2,050	(42)	840	(32)
	09	444	(18)	595	(32)	1,208	(22)
Floor	01	490	(32)	310	(66)	200	(42)
	02	200	(32)	60	(66)	160	(40)
	03	180	(31)	130	(60)	160	(35)
	05	280	(26)	510	(45)	250	(33)

TABLE 4-40. INTERIOR DUST LOADINGS (mg dust/m^2)

	Phas	Area A G.M.	Area A (n)	Area B G.M.	Area B (n)	Area C G.M.	Area C (n)
Window	01	740	(32)	1,340	(64)	1,640	(42)
	02	550	(30)	470	(60)	1,470	(39)
	03	260	(29)	270	(60)	420	(35)
	05	3,110	(26)	6,410	(45)	5,510	(33)
Mat	01	100	(31)	100	(60)	90	(40)
	02	550	(33)	300	(64)	210	(40)
	03	580	(28)	530	(57)	380	(36)
	05	570	(25)	1,320	(39)	360	(32)

Immediately post-abatement in Area A (interior and exterior abatement) and in Area B (interior abatement) the difference in hand lead between areas was no longer statistically significant. At about 3 mo post-abatement (Phase 03) hand lead values in Area C were significantly lower than those in either Areas A or B. No further statistically significant differences in hand lead occurred for the balance of the study.

Over the course of the two year study, hand leads changed from being lower in Area C to being similar in all three areas. The abatements implemented in Areas A and B may have had a role in "equalizing" the lead exposures among the three study areas. In Table 4-47

TABLE 4-41. BLOOD LEAD CONCENTRATIONS BY PHASE AND STUDY AREA (μG Pb/dL) (Initial Recruits, Rehabilitated Housing)

	Area A			Area B			Area C		
Phase/[Abatement]	G.M.	(LCL-UCL)	(n)	G.M.	(LCL-UCL)	(n)	G.M.	(LCL-UCL)	(n)
01 (June-July 1989)	8.89	(7.62–10.36)	(54)	10.60	(9.48–11.85)	(85)	7.96	(6.92–9.15)	(61)
Aug.-Sept. 1989	Interior & Exterior Dust and Soil Abatement			Interior Dust Abatement					
03 (Nov.-Dec. 1989)	7.01	(5.94–8.26)	(52)	9.15	(8.24–10.17)	(79)	5.77	(5.00–6.66)	(52)
05 (June-July 1990)	8.88	(7.61–10.37)	(46)	8.69	(7.60–9.94)	(67)	6.97	(5.86–8.30)	(49)
Aug.-Sept. 1990				Exterior Dust and Soil Abatement					
07 (Nov.-Dec. 1990)	8.24	(7.01–9.68)	(37)	7.53	(6.64–8.53)	(61)	7.34	(6.38–8.44)	(40)
09 (June-July 1991)	8.84	(7.40–10.38)	(31)	8.99	(8.03–10.07)	(53)	8.03	(6.95–9.26)	(33)

G.M. = geometric mean; LCL = lower confidence limit of geometric mean; UCL = upper confidence limit of geometric mean; n = number of samples.

TABLE 4-42. BLOOD LEAD BY AREA AND PHASE (PAIRED DATA) (μG Pb/dL) (Initial Recruits, Rehabilitated Housing)

Phases	Area A G.M.	Area A (n)	Area A (LCL-UCL)	Area B G.M.	Area B (n)	Area B (LCL-UCL)	Area C G.M.	Area C (n)	Area C (LCL-UCL)
01	8.92	(50)	(7.57–10.49)	10.94	(77)	(9.79–12.23)	8.41	(47)	(7.28–9.70)
03	7.41	(50)	(6.37–8.62)	9.40	(77)	(8.50–10.40)	5.97	(47)	(5.11–6.97)
01	8.36	(43)	(7.06–9.90)	10.79	(61)	(9.61–12.11)	8.49	(41)	(7.25–9.95)
05	9.16	(43)	(7.80–10.76)	9.27	(61)	(8.21–10.46)	7.29	(41)	(6.08–8.75)
01	8.18	(32)	(6.74–9.91)	10.41	(54)	(9.24–11.74)	8.47	(33)	(7.04–10.19)
07	9.13	(32)	(7.81–10.68)	8.29	(54)	(7.47–9.20)	7.41	(33)	(6.38–8.60)
01	8.26	(27)	(6.71–10.17)	10.57	(48)	(9.35–11.96)	9.23	(26)	(7.59–11.24)
09	8.94	(27)	(7.47–10.69)	8.90	(48)	(8.04–9.86)	8.24	(26)	(7.27–9.33)
03	7.16	(33)	(5.83–8.80)	8.77	(56)	(7.75–9.91)	6.33	(36)	(5.37–7.46)
07	8.99	(33)	(7.70–10.49)	8.28	(56)	(7.48–9.17)	7.36	(36)	(6.35–8.53)
05	8.88	(28)	(7.13–11.07)	8.08	(50)	(6.91–9.46)	7.09	(29)	(5.57–9.03)
09	9.10	(28)	(7.66–10.82)	8.83	(50)	(7.95–9.82)	8.04	(29)	(6.97–9.27)

G.M. = geometric mean; LCL = lower confidence level of geometric mean; UCL = upper confidence level of geometric mean; n = number of samples.

Interior dust abatement occurred between Phases 01 and 03 in Areas A and B. Soil and exterior dust abatement occurred between Phases 01 and 01 in Area A and between Phases 05 and 07 in Area B.

TABLE 4-43.
(a) RATIO OF BLOOD LEAD LEVELS FROM PHASE TO PHASE
(Initial Recruits, Rehabilitated Housing)

	Area A			Area B			Area C		
Phases	G.M.	(n)	(LCL-UCL)	G.M.	(n)	(LCL-UCL)	G.M.	(n)	(LCL-UCL)
3 to 1	0.83	(50)	(0.74–0.94)	0.86	(77)	(0.80–092)	0.71	(47)	(0.62–0.81)
5 to 1	1.10	(43)	(0.91–1.31)	0.86	(61)	(0.75–0.97)	0.86	(41)	(0.71–1.04)
7 to 1	1.12	(32)	(0.91–1.37)	0.80	(53)	(0.71–0.90)	0.87	(33)	(0.73–1.05)
9 to 1	1.08	(27)	(0.84–1.39)	0.84	(48)	(0.74–0.96)	0.88	(26)	(0.74–1.06)

(b) DIFFERENCES IN BLOOD LEAD LEVELS BETWEEN PHASES
μg Pb/dL
(Initial Recruits, Rehabilitated Housing)

	Area A			Area B			Area C		
Phases	Mean	(n)	(LCL-UCL)	Mean	(n)	(LCL-UCL)	Mean	(n)	(LCL-UCL)
3 to 1	-1.86	(50)	(-3.07 to -0.65)	-1.86	(77)	(-2.61 to -1.11)	-2.55	(47)	(-3.61 to -1.44)
5 to 1	0.87	(43)	(-0.80 to 2.54)	-1.51	(61)	(-2.81 to -0.22)	-0.96	(41)	(-2.47 to 0.54)
7 to 1	0.76	(32)	(-1.16 to 2.67)	-2.46	(53)	(-3.76 to -1.17)	-1.50	(33)	(-2.93 to -0.07)
9 to 1	0.64	(27)	(-1.86 to 3.14)	-2.04	(48)	(-3.35 to -0.73)	-1.72	(26)	(-3.53 to 0.09)

G.M. = geometric mean; LCL = lower confidence level of geometric mean; UCL = upper confidence level of geometric mean; n = number of samples.

Interior dust abatement occurred between Phases 01 and 03 in Areas A and B. Soil and exterior dust abatement occurred between Phases 01 and 01 in Area A and between Phases 05 and 07 in Area B.

TABLE 4-44. SUMMARY OF BLOOD LEAD BY AGE AND HOUSE TYPE PHASE 01[a]

Age Range, Years[b]	House Type	Blood Lead G.M.	Blood Lead (n)	Blood Lead (LCL-UCL)
Less than 1	Rehabilitated	5.83	(34)	(4.87–6.99)
1 to <2	Rehabilitated	10.30	(38)	(8.71 –12.18)
2 to <3	Rehabilitated	12.54	(29)	(11.03–14.26)
3 to <4	Rehabilitated	10.51	(37)	(9.11–12.12)
4 to <5	Rehabilitated	9.98	(28)	(8.38–11.89)
5 to <6	Rehabilitated	12.67	(8)	(8.80–18.25)
Less than 1	Other	7.20	(4)	(5.88–8.83)
1 to <2	Other	11.61	(2)	(4.87–27.72)
2 to <3	Other	21.45	(1)	
3 to <4	Other	17.61	(3)	(10.00–31.00)
4 to <5	Other	18.64	(3)	(12.78–27.17)
5 to <6	Other		(0)	

[a]Table represents blood lead at Phase 01 for children for whom Phase 03 blood lead data is also available.
[b]Age at Phase 01 recruitment.

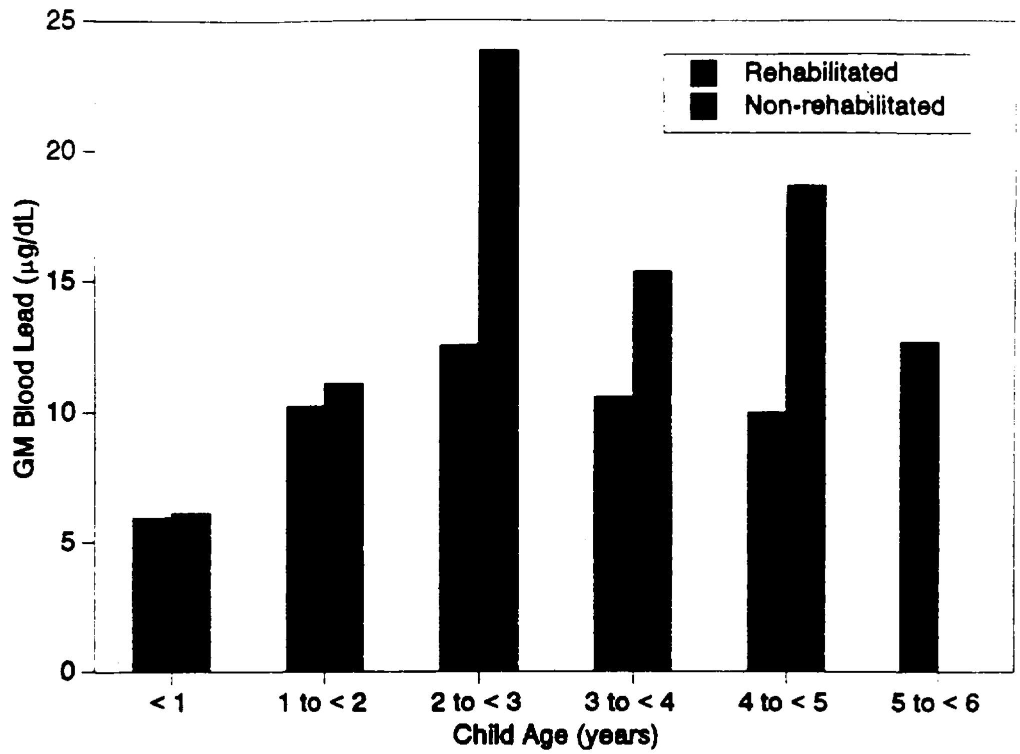


Figure 4-24. Effect of child age and house type on blood lead.

and Figures 4-27 and 4-28 a reduced set of data is used to compare hand lead values between pairs of phases using only data that are available for children active in *both* phases. In this paired phase analysis, the geometric mean hand lead for Area C remained significantly lower than that for both Areas A and B through Phase 05; for Phase 06 it was lower than that of Area A, for Phase 07 it was lower than that for Area B and for Phase 09 it was lower than the geometric mean for both Areas A and B. Thus the overall conclusion is the same as that previously stated for the more complete data set: hand lead values were initially lower in Area C than for the other study areas but at the end of the study they were not statistically significant than geometric mean values in the other areas.

Hand lead comparison by study group between specific pairs of phases (e.g., 1 and 2), for children active in the study for both phases, are shown in Table 4-47 and Figures 4-27 and 4-28. Only Area A showed a decline in mean hand lead between Phases 01 and 02 (Figure 4-28); all areas showed decline between Phase 01 and 03.

TABLE 4-45. RATIO OF BLOOD LEAD LEVELS FROM PHASE TO PHASE BY AGE AND AREA (Initial Recruits, Rehabilitated Housing)

	Area A		Area B		Area C	
Phase[a]/Age[b]	G.M. (n)	(LCL-UCL)	G.M. (n)	(LCL-UCL)	G.M. (n)	(LCL-UCL)
5 to 1/less than 1	2.40 (9)	(1.74-3.32)	1.29 (11)	(0.95-1.75)	1.40 (8)	(0.63-3.10)
1 to <2	0.69 (8)	(0.43-1.12)	0.90 (15)	(0.69-1.17)	0.84 (9)	(0.65-1.07)
2 to <3	0.84 (9)	(0.65-1.07)	0.85 (6)	(0.64-1.13)	0.83 (8)	(0.60-1.16)
3 to <4	0.99 (8)	(0.90-1.10)	0.80 (16)	(0.70-0.91)	0.66 (8)	(0.55-0.80)
4 to <5	1.08 (9)	(0.86-1.34)	0.76 (8)	(0.62-0.95)	0.79 (5)	(0.73-0.85)
5 to <6	0		0.47 (5)	(0.29-0.77)	0.64 (3)	(0.48-0.85)
9 to 1/less than 1	2.32 (6)	(1.32-4.05)	1.44 (8)	(1.12-1.85)	1.41 (5)	(0.88-2.24)
1 to <2	0.91 (5)	(0.49-1.70)	0.81 (11)	(0.58-1.13)	0.72 (5)	(0.52-1.01)
2 to <3	1.19 (6)	(0.62-1.22)	1.17 (4)	(0.67-1.22)	1.12 (5)	(0.90-1.42)
3 to <4	0.76 (6)	(0.62-0.94)	0.71 (14)	(0.62-0.81)	0.79 (5)	(0.52-1.19)
4 to <5	1.01 (4)	(0.59-1.71)	0.81 (7)	(0.64-1.02)	0.61 (4)	(0.43-0.86)
5 to <6	0		0.58 (4)	(0.41-0.82)	0.70 (2)	(0.59-0.83)

[a] Phase 01 (June-July 1989)*, Phase 02 (June-July 1990)**, Phase 03 (June-July 1991)***.
[b] Age at time of initial recruitment in Phase 01.

* pre-abatement.
** 10 mo post-abatement in Area A (soil, exterior dust, interior dust) and Area B (interior dust)
*** 22 mo post-abatement in Area A (soil, exterior dust, interior dust) and Area B (interior dust); and 10 mo post-exterior dust and soil abatement in Area B.

G.M. = geometric mean; LCL = lower confidence level of geometric mean; UCL = upper confidence level of geometric mean; n = number of samples.

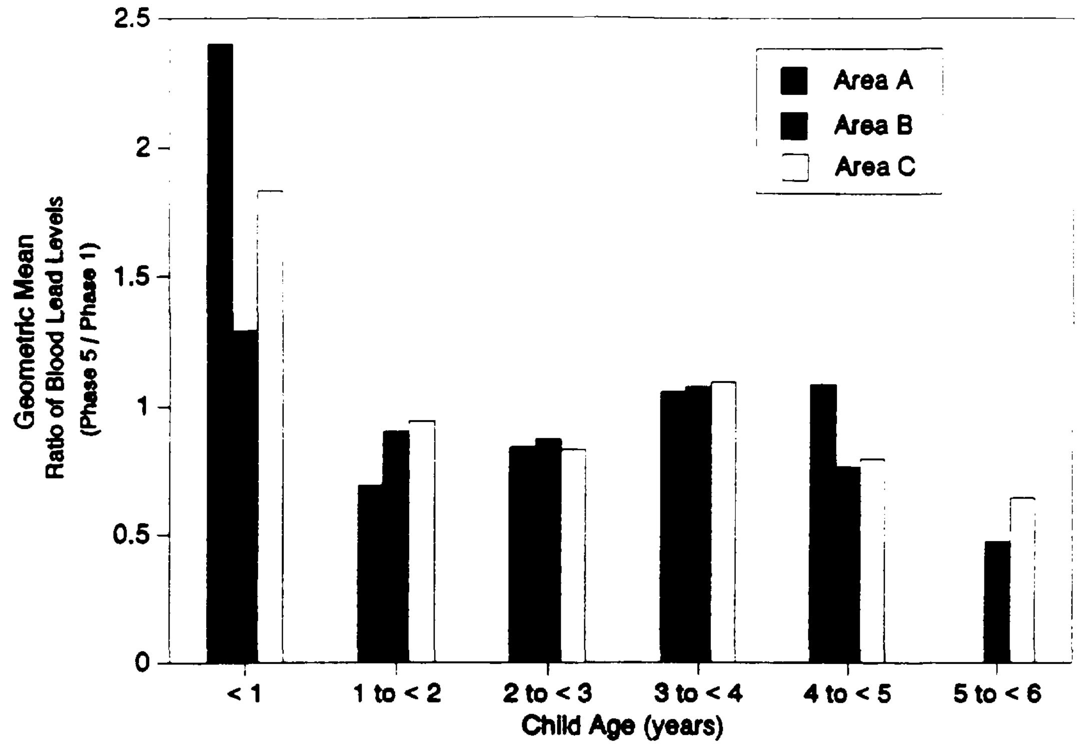


Figure 4-25. Impact of abatement on children living in rehabilitated housing, Phase 5 versus Phase 1.

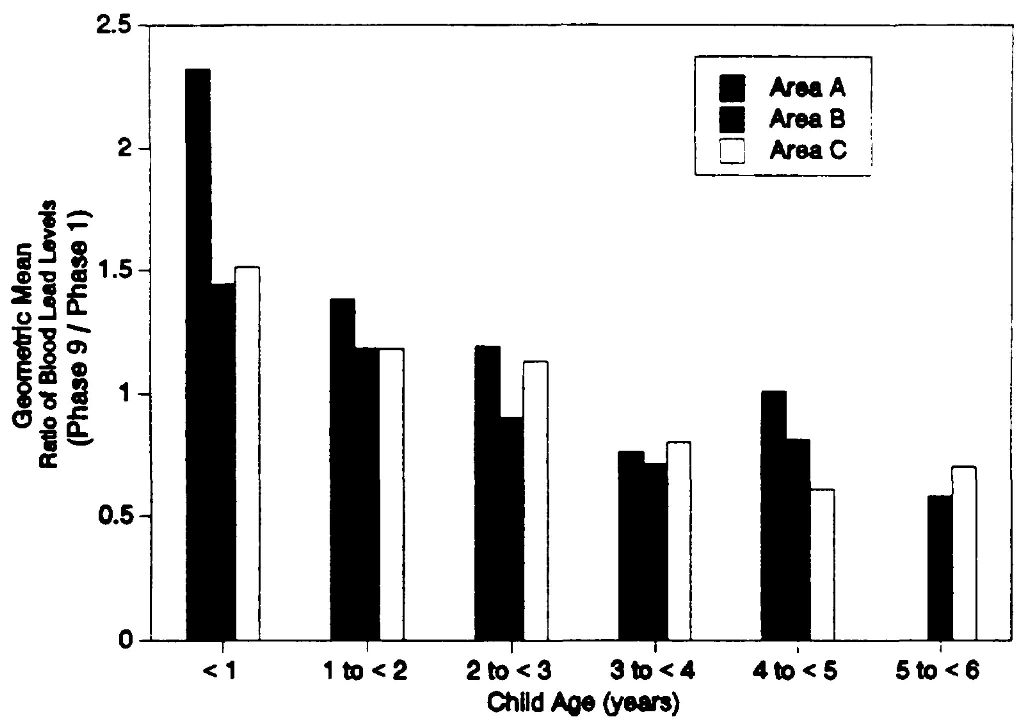


Figure 4-26. Impact of abatement on children living in rehabilitated housing, Phase 9 versus Phase 1.

TABLE 4-46. HAND LEAD
μg Lead, Both Hands
(Initial Recruits, Rehabilitated Housing)

	Area A			Area B			Area C		
Phase/[Abatement]	G.M.	(LCL-UCL)	(n)	G.M.	(LCL-UCL)	(n)	G.M.	(LCL-UCL)	(n)
01 (June-July 1989)	6.71	(5.42–8.27)	(49)	7.93	(6.25–10.00)	(80)	3.29	(2.40–4.42)	(54)
Aug.-Sept. 1989		INTERIOR & EXTERIOR DUST AND SOIL ABATEMENT			INTERIOR DUST ABATEMENT				
02 (Aug.-Sept. 1989)	4.96	(3.69–6.57)	(49)	6.90	(5.51–8.59)	(74)	2.86	(2.11–3.78)	(57)
03 (Nov.-Dec. 1989)	4.79	(3.64–6.21)	(35)	4.99	(3.94–6.26)	(62)	1.99	(1.34–2.81)	(40)
05 (June-July 1990)	11.40	(8.32–15.49)	(37)	8.92	(6.59–11.98)	(59)	4.46	(3.10–6.27)	(44)
Aug.-Sept. 1990					EXTERIOR DUST & SOIL ABATEMENT				
06 (Aug.-Sept. 1990)	11.78	(8.74–15.77)	(30)	7.93	(5.81–10.70)	(44)	6.61	(5.09–8.51)	(34)
07 (Nov.-Dec. 1990)	5.63	(3.29-9.26)	(28)	7.29	(5.23–10.04)	(54)	4.28	(2.97–6.02)	(34)
09 (June-Sept. 1991)	12.01	(7.85–18.12)	(28)	17.16	(12.79–22.91)	(48)	11.01	(7.29–16.38)	(30)

G.M. = geometric mean; LCL = lower confidence limit of geometric mean; UCL = upper confidence limit of geometric mean; n = number of samples.

TABLE 4-47. COMPARISON OF HAND LEAD VALUES BETWEEN PAIRS OF PHASES*
μg Lead, Both Hands
(Initial Recruits, Rehabilitated Housing)

	Area A			Area B			Area C		
Phases	G.M.	(LCL-UCL)	(n)	G.M.	(LCL-UCL)	(n)	G.M.	(LCL-UCL)	(n)
1	6.52	(5.23–8.08)	(44)	7.94	(6.17–10.14)	(71)	3.20	(2.31–4.32)	(51)
2	4.77	(3.53–6.35)	(44)	6.82	(5.41–8.54)	(71)	2.76	(1.98–3.74)	(51)
1	6.98	(5.29–9.21)	(32)	7.17	(5.56–9.18)	(58)	3.49	(2.35–5.03)	(32)
3	4.80	(3.56–6.37)	(32)	5.20	(4.11–6.54)	(58)	2.02	(1.32–2.94)	(32)
1	7.28	(5.45–9.63)	(31)	7.93	(5.86–10.62)	(51)	3.34	(2.19–4.91)	(36)
5	11.70	(8.26–16.41)	(31)	11.41	(8.86–14.61)	(51)	5.04	(3.36–7.36)	(36)
1	6.98	(5.04–9.54)	(28)	7.29	(5.15–10.17)	(39)	3.80	(2.39–5.79)	(27)
6	11.90	(8.76–16.06)	(28)	8.30	(5.94–11.46)	(39)	6.47	(4.83–8.58)	(27)
1	6.34	(4.47–8.85)	(23)	9.46	(6.87–12.90)	(42)	3.90	(2.37–6.11)	(28)
7	6.93	(4.14–11.24)	(23)	8.74	(6.13–12.30)	(42)	4.24	(2.83–6.19)	(28)
1	7.51	(5.16–10.76)	(22)	8.33	(5.75–11.91)	(36)	4.53	(2.79–7.09)	(25)
9	13.15	(8.12–20.96)	(22)	19.47	(13.89–27.15)	(36)	10.41	(6.59–16.17)	(25)

*Using only data available for each phase being compared.

G.M. = geometric mean; LCL = lower confidence limit of geometric mean; UCL = upper confidence limit of geometric mean; n = number of samples

Interior dust abatement occurred between Phases 01 and 02 in Areas A and B. Soil and exterior dust abatement occurred between Phases 01 and 01 in Area A and between Phases 05 and 06 in Area B.

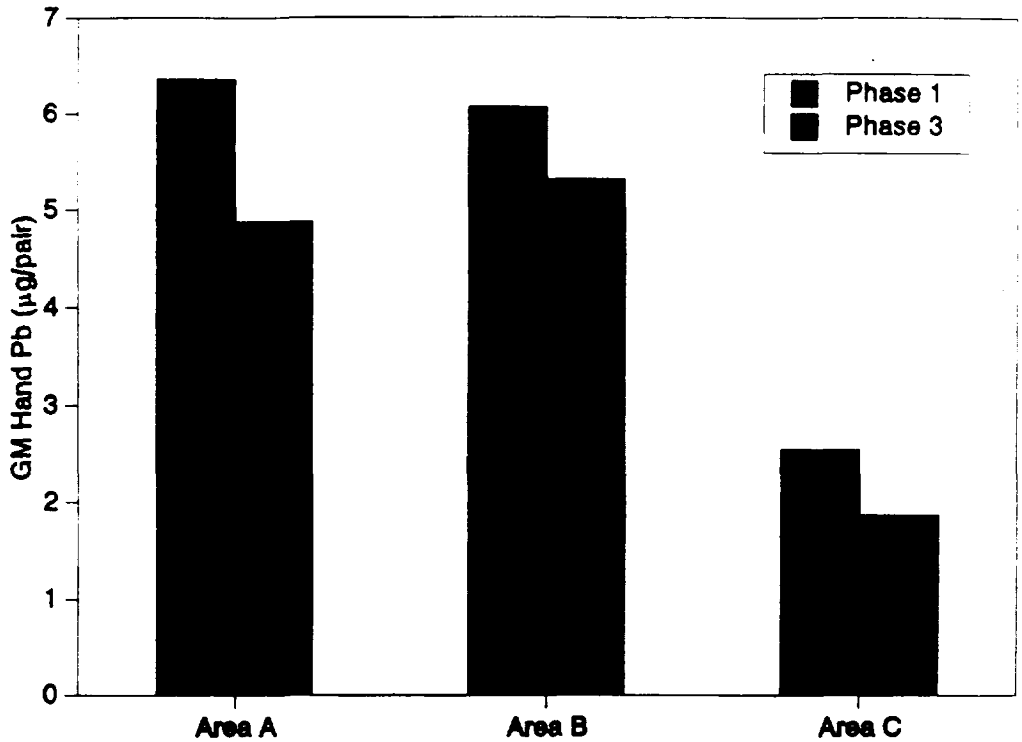


Figure 4-27. Comparison of hand lead loading between Phase 1 and Phase 3.

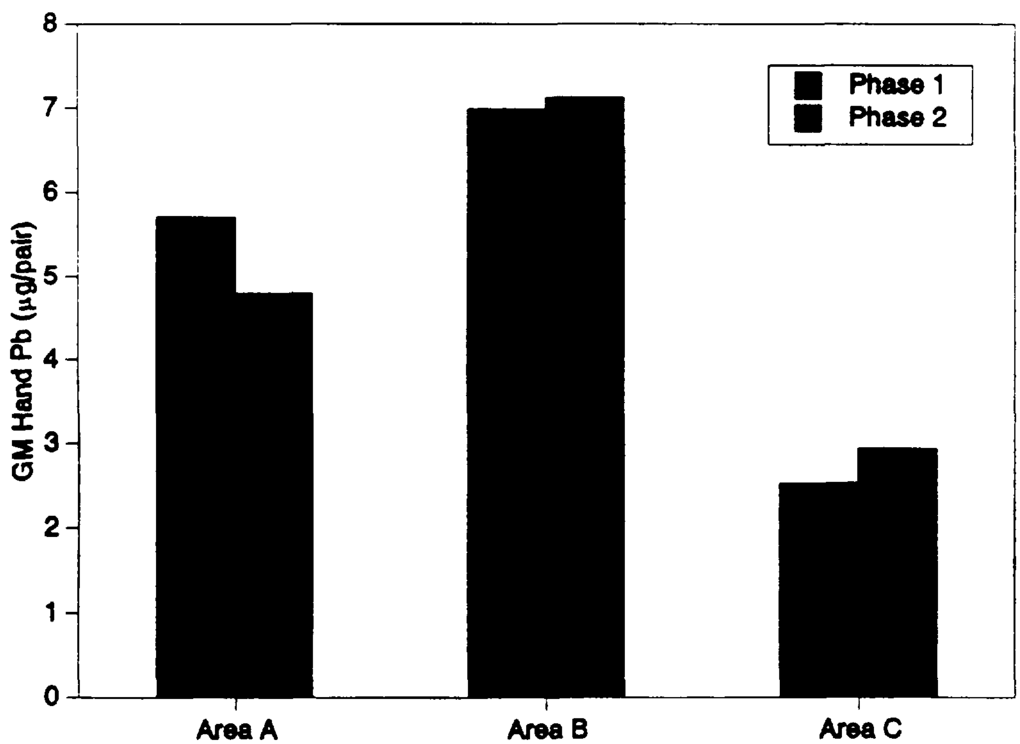


Figure 4-28. Comparison of hand lead loading between Phase 1 and Phase 2.

TABLE 4-48. INTERCORRELATIONS* BETWEEN BLOOD LEAD AND HAND LEAD AND ENVIRONMENTAL LEAD MEASURES AND AGE (Pearson Correlations) FOR OVERALL STUDY POPULATION AND BY AREA (Phase 01) (arithmetic)

	Blood Lead				Hand Lead			
	Overall	A	B	C	Overall	A	B	C
PbB	1.00	1.00	1.00	1.00	0.47 0.0001 202	0.52 0.0001 51	0.44 0.0001 95	0.28 0.04 56
PbH	0.47 0.0001 202	0.52 0.0001 51	0.44 0.0001 95	0.28 0.04 56	1.00	1.00	1.00	1.00
Interior Entry Dust Loading					0.41 0.0001 193		0.50 0.0001 95	
Interior Entry Dust Concn.	0.27 0.0003 181	0.55 0.0002 40	0.21 0.05 91	0.36 0.01 50	0.39 0.0001 186	0.62 0.0001 40	0.57 0.0001 94	
Interior Floor Dust Pb Loading					0.45 0.0001 195		0.54 0.0001 96	
Interior Floor Dust Pb Concn.	0.21 0.003 190	0.45 0.002 44		0.37 0.006 57	0.48 0.0001 195	0.85 0.0001 44	0.31 0.002 96	
Interior Window Dust Pb Loading							0.26 0.01 92	
Interior Window Dust Concn.	0.18 0.01 186	0.55 0.0001 44		0.34 0.01 53	0.35 0.0001 191	0.93 0.0001 44		
Interior Mat Lead Loading	0.27 0.0002 188	0.33 0.03 45	0.27 0.01 90		0.34 0.0001 193	0.69 0.0001 45	0.34 0.001 93	
Interior Mat Concn.	0.21 0.004 180				0.35 0.0001 185	0.73 0.0001 43	0.31 0.003 89	
Exterior Dust Max Conc.								

TABLE 4-48 (cont'd). INTERCORRELATIONS* BETWEEN BLOOD LEAD AND HAND LEAD AND ENVIRONMENTAL LEAD MEASURES AND AGE (Pearson Correlations) FOR OVERALL STUDY POPULATION AND BY AREA (Phase 01) (arithmetic)

	Blood Lead				Hand Lead			
	Overall	A	B	C	Overall	A	B	C
Age	0.34 0.0001 202		0.44 0.0001 95	0.41 0.002 56	0.34 0.0001 202	0.35 0.01 51	0.34 0.0006 95	0.38 0.003 56
Age-Squared	0.25 0.0003 202		0.36 0.0004 95	0.30 0.03 56	0.31 0.0001 202	0.36 0.009 51	0.29 0.004 95	0.33 0.01 56
Paint-Interior Trim (Max)			0.29 0.01 70					
Paint-Exterior Trim			0.26 0.03 70					

*Top number is correlation coefficient, middle is significance level and bottom is number of observations. Only correlations with statistical significance ≤0.05 are shown.

Phase 01 is pre-abatement.

4.10 INTERCORRELATIONS

Intercorrelation between blood lead and hand lead and environmental dust, paint and age variables are presented in Tables 4-48 to 4-51 for Phases 01, 03, 05 and 09, respectively. Only correlations significant at $p \leq 0.05$ are shown. The number of significant correlations decreased markedly after the abatements that occurred after Phase 01. Table 4-52 contains all correlations for Phases 01-09, regardless of their statistical significance, and using log transformed data. Correlations between blood lead and hand lead are summarized in Table 4-53.

A comparison of preabatement intercorrelations among environmental and blood lead data between the Cincinnati prospective study (Clark et al., 1991) and those of the soil project (Table 4-54) revealed similar patterns except for paint lead (XRF, mg Pb/cm^2). The prospective study invalues a wide range of housing types from rehabilitated housing to

TABLE 4-49. INTERCORRELATIONS* BETWEEN BLOOD LEAD AND HAND LEAD AND ENVIRONMENTAL LEAD MEASURES AND AGE (Pearson Correlations) FOR OVERALL STUDY POPULATION AND BY AREA (Phase 03) (arithmetic)

	Blood Lead				Hand Lead			
	Overall	A	B	C	Overall	A	B	C
Blood Lead	1.00	1.00	1.00	1.00	0.51 0.0001 151		0.62 0.0001 75	
Hand Lead	0.51 0.0001 151		0.62 0.0001 75		1.00	1.00	1.00	1.00
Interior Entry Dust Pb Loading		0.33 0.05 35					−0.23 0.05 76	
Interior Entry Dust Pb Concn.								
Interior Floor Pb Dust Loading								
Interior Floor Dust Pb Concn.								
Interior Window Dust Pb Loading								
Interior Window Dust Pb Concn.								
Interior Mat Pb Loading								
Interior Mat Pb Concn.								
Exterior Dust Pb Concn. Max					0.23 0.009 130			

TABLE 4-49 (cont'd). INTERCORRELATIONS* BETWEEN BLOOD LEAD AND HAND LEAD AND ENVIRONMENTAL LEAD MEASURES AND AGE (Pearson Correlations) FOR OVERALL STUDY POPULATION AND BY AREA (Phase 01) (arithmetic)

	Blood Lead				Hand Lead			
	Overall	A	B	C	Overall	A	B	C
Paint Pb Interior Trim Max	0.22 0.01 133		0.37 0.003 62		0.46 0.0001 134		0.61 0.0001 63	
Paint Pb Interior Wall Max			0.31 0.01 62		0.22 0.01 135		0.58 0.0001 63	
Paint Pb Exterior Trim					0.37 0.0002 135		0.57 0.0001 63	
Paint Pb Exterior Walls			0.31 0.02 59		0.34 0.0002 119		0.57 0.0001 60	
Age	0.28 0.0006 151		0.38 0.0009 75		0.32 0.0001 151	0.38 0.02 35	0.28 0.01 75	0.55 0.0002 41
Age-Squared	0.22 0.006 151		0.33 0.004 75		0.28 0.0005 151	0.35 0.04 35	0.24 0.03 75	0.49 0.001 41

*Top number is correlation coefficients, middle is significance level and bottom is number of observations. Only correlations with statistical significant 0.05 are shown.

Phase 03 is about 3 mo after abatements in Area A (exterior and interior dust and soil) and in Area B (interior dust only).

19th century dilapidated housing while the soil project included primarily rehabilitated (lead paint free) housing. As expected intercorrelation involving paint lead were not statistically significant for the soil project while they were for the prospective study.

TABLE 4-50. INTERCORRELATIONS* BETWEEN BLOOD LEAD AND HAND LEAD AND ENVIRONMENTAL LEAD MEASURES AND AGE (Pearson Correlations) FOR OVERALL STUDY POPULATION AND BY AREA (Phase 05) (arithmetic)

	Blood Lead				Hand Lead			
	Overall	A	B	C	Overall	A	B	C
Blood Lead	1.00	1.00	1.00	1.00	0.34 0.0001 149		0.51 0.0001 68	
Hand Lead	0.34 0.0001 149		0.51 0.0001 68		1.00	1.00	1.00	1.00
Interior Floor Dust Pb Loading								
Interior Floor Dust Pb Concn.	0.17 0.04 147							
Interior Entry Dust Pb Loading								
Interior Entry Dust Pb Concn.	0.19 0.02 146						0.28 0.02 68	0.32 0.04 42
Interior Window Dust Pb Loading								
Interior Window Dust Pb Concn.								
Exterior Dust Pb Concn. Max	0.16 0.05 145			0.31 0.04 143	0.17 0.04 145			
Age					0.27 0.0007 149	0.33 0.05 37	0.25 0.04 68	0.44 0.003 44

TABLE 4-50. INTERCORRELATIONS* BETWEEN BLOOD LEAD AND HAND LEAD AND ENVIRONMENTAL LEAD MEASURES AND AGE (Pearson Correlations) FOR OVERALL STUDY POPULATION AND BY AREA (Phase 05) (arithmetic)

	Blood Lead				Hand Lead			
	Overall	A	B	C	Overall	A	B	C
Blood Lead	1.00	1.00	1.00	1.00	0.34 0.0001 149		0.51 0.0001 68	
Hand Lead	0.34 0.0001 149		0.51 0.0001 68		1.00	1.00	1.00	1.00
Interior Floor Dust Pb Loading								
Interior Floor Dust Pb Concn.	0.17 0.04 147							
Interior Entry Dust Pb Loading								
Interior Entry Dust Pb Concn.	0.19 0.02 146						0.28 0.02 68	0.32 0.04 42
Interior Window Dust Pb Loading								
Interior Window Dust Pb Concn.								
Exterior Dust Pb Concn. Max	0.16 0.05 145			0.31 0.04 143	0.17 0.04 145			
Age					0.27 0.0007 149	0.33 0.05 37	0.25 0.04 68	0.44 0.003 44

TABLE 4-50 (cont'd). INTERCORRELATIONS* BETWEEN BLOOD LEAD AND HAND LEAD AND ENVIRONMENTAL LEAD MEASURES AND AGE (Pearson Correlations) FOR OVERALL STUDY POPULATION AND BY AREA (Phase 05) (arithmetic)

	Blood Lead				Hand Lead			
	Overall	A	B	C	Overall	A	B	C
Age- Squared					0.28 0.0007 149	0.38 0.02 37		0.45 0.002 44
Interior Mat Dust Pb Loading	0.18 0.03 145							
Interior Mat Dust Pb Concn.	0.41 0.0001 137		0.40 0.002 59	0.41 0.006 43	0.28 0.0008 137		0.49 0.0001 59	
Interior Wall Paint Pb Max			0.30 0.01 68			0.34 0.05 34		
Interior Trim Paint Pb Max	0.22 0.007 146		0.36 0.003 68					
Exterior Paint Pb		0.36 0.03 35						

*Top number is correlation coefficient, middle is significance level and bottom is number of observations. Only correlations with statistical significance 0.05 are shown.

Phase 05 is about 10 mo past abatement in Area A (interior and exterior dust and soil) and in Area B (interior dust only).

4.11 MODELING

4.11.1 Modeling the Difference of Phase 1 and Phase 5 Blood Lead for the Initially Recruited Families Who Lived in the Rehabilitated Housing Units

We evaluated the effectiveness of soil lead and dust abatement through analyzing the data collected before and after initial abatement, e.g., Phase 1 and Phase 5. In Area "A", exterior dust (lead concentration), interior dust (lead concentration) and soil lead were abated

TABLE 4-51 (cont'd). INTERCORRELATIONS* BETWEEN BLOOD LEAD AND HAND LEAD AND ENVIRONMENTAL LEAD MEASURES AND AGE (Pearson Correlations) FOR OVERALL STUDY POPULATION AND BY AREA (Phase 09) (arithmetic)

	Blood Lead				Hand Lead			
	Overall	A	B	C	Overall	A	B	C
Interior Trim Paint Pb Max	0.36 0.0001 107		0.50 0.0002 50					
Exterior Trim Paint Pb	0.36 0.0001 107		0.48 0.0005 50					
Exterior Window Paint Pb			0.53 0.0002 45					
Age					0.21 0.03 109		0.28 0.05 51	
Age-Squared					0.20 0.04 109			

*Top number is correlation coefficients, middle is significance level and bottom is number of observations. Only correlations with statistical significance 0.05 are shown.
Phase 09 is about 22 mo post abatement in Area A (interior and exterior dust and soil) and about 22 mo post interior dust abatement in Area B and about 10 mo post exterior dust and soil abatement in Area B.

after Phase 1. In Area "B", interior dust was abated after Phase 1. In Area "C", no abatement occurred during this time period.

Based on our data analysis, we found that the mean difference of blood lead between Phase 1 and Phase 5 (DPbB) in Area "A" was greater than that in Area "C", e.g., DPbB in Area "A" was 2.13 mg/dL more than in Area "C" (i.e., blood leads increased in Area A relative to Area C). The mean difference of handwipe lead between Phase 1 and Phase 5 (DPbH) had no significant influence to the difference of blood lead between Phase 1 and Phase 5. The mean difference of interior house dust lead loading between Phase 1 and Phase 5 (DPbDIMD) significantly affected the difference of blood lead between Phase 1 and Phase 5. In other words, in Area "A", DPbB increased 2.13 mg/dL for per mg/m^2 increase

TABLE 4-52. INTERCORRELATIONS BETWEEN BLOOD LEAD AND HAND LEAD AND ENVIRONMENTAL LEAD MEASURES AND AGE

For overall study population and by area
(logarithmic)

		Blood Lead				Hand Lead			
Factor	Phase	Overall	A	B	C	Overall	A	B	C
Hand Lead	01	0.51**	0.40*	0.52**	0.48*				
		(202)	(51)	(95)	(56)				
	03	0.40**	0.09	0.53**	0.11				
		(151)	(35)	(75)	(41)				
	05	0.41**	0.26	0.61**	0.10				
		(149)	(37)	(68)	(44)				
	09	0.37**	0.33	0.37*	0.36*				
		(109)	(28)	(51)	(30)				
Interior Entry Dust Loading	01	0.05	0.07	0.17	-0.10	0.32**	0.32*	0.36*	0.28*
		(188)	(43)	(92)	(53)	(193)	(43)	(95)	(55)
	03	0.07	0.14	-0.06	0.00	-0.03	-0.12	-0.13	-0.06
		(151)	(35)	(75)	(41)	(152)	(38)	(76)	(41)
	05	0.23*	0.16	0.21	0.17	0.20*	0.22	0.15	0.03
		(149)	(37)	(68)	(44)	(149)	(37)	(68)	(44)
	09	0.08	0.00	0.02	0.28	-0.03	0.12	-0.13	-0.02
		(106)	(28)	(48)	(30)	(108)	(28)	(49)	(31)
Interior Entry Dust Pb Concn.	01	0.29**	0.36*	0.20	0.19	0.42**	0.35**	0.47**	0.14
		(181)	(40)	(91)	(50)	(186)	(40)	(94)	(52)
	03	0.13	-0.17	-0.06	0.19	0.06	0.09	-0.08	-0.14
		(151)	(35)	(75)	(41)	(152)	(35)	(76)	(41)
	05	0.25	0.22	0.25*	0.19	0.37**	0.28	0.34*	0.45*
		(146)	(36)	(68)	(42)	(146)	(36)	(68)	(42)
	09	0.13	0.11	0.06	0.21	0.16	0.12	0.26	-0.07
		(106)	(28)	(48)	(30)	(108)	(28)	(49)	(31)

TABLE 4-52 (cont'd). INTERCORRELATIONS BETWEEN BLOOD LEAD AND HAND LEAD AND ENVIRONMENTAL LEAD MEASURES AND AGE
For overall study population and by area
(logarithmic)

		Blood Lead				Hand Lead			
Factor	Phase	Overall	A	B	C	Overall	A	B	C
Interior Floor Dust Pb Loading	01	0.11	0.06	0.12	0.03	0.32**	0.34*	0.28*	0.18
		(190)	(44)	(93)	(53)	(195)	(44)	(96)	(55)
	03	0.13	0.12	0.02	0.09	0.04	-0.16	0.01	-0.12
		(151)	(35)	(75)	(41)	(152)	(35)	(76)	(41)
	05	0.19*	0.07	0.16	0.15	0.23*	0.03	0.17	0.19
		(147)	(37)	(68)	(42)	(147)	(37)	(68)	(42)
	09	a	a	a	a	a	a	a	a
Interior Floor Dust Pb Concn.	01	0.18*	0.20	0.01	0.19	0.38**	0.39*	0.25*	0.30*
		(190)	(44)	(93)	(53)	(195)	(44)	(96)	(55)
	03	0.14	0.04	-0.05	-0.06	0.18*	0.08	0.07	-0.12
		(150)	(35)	(75)	(40)	(151)	(35)	(76)	(40)
	05	0.18*	0.16	0.11	0.08	0.31**	0.10	0.20	0.30*
		(147)	(37)	(68)	(42)	(147)	(37)	(68)	(42)
	09	a	a	a	a	a	a	a	a
Interior Window Dust Pb Loading	01	0.04	0.07	0.15	-0.11	0.19*	0.31*	0.25*	0.08
		(186)	(44)	(89)	(53)	(191)	(44)	(92)	(55)
	03	0.09	0.25	-0.12	0.00	0.07	0.01	-0.08	0.10
		(149)	(33)	(75)	(41)	(150)	(33)	(76)	(41)
	05	0.18*	0.29	0.09	0.17	0.10	0.20	0.03	0.03
		(149)	(37)	(68)	(44)	(149)	(37)	(68)	(44)
	09	a	a	a	a	a	a	a	a

TABLE 4-52 (cont'd). INTERCORRELATIONS BETWEEN BLOOD LEAD AND HAND LEAD AND ENVIRONMENTAL LEAD MEASURES AND AGE
For overall study population and by area
(logarithmic)

		Blood Lead				Hand Lead			
Factor	Phase	Overall	A	B	C	Overall	A	B	C
Exterior Entry Dust Pb Concn. (median)	01	0.15*	0.07	-0.02	0.03	0.27**	0.08	0.02	0.10
		(195)	(49)	(92)	(54)	(200)	(49)	(95)	(56)
	03	0.18*	-0.06	-0.09	-0.01	0.22*	-0.27	0.01	-0.09
		(130)	(26)	(71)	(33)	(130)	(26)	(71)	(43)
	05	0.23*	0.14	0.03	0.35*	0.37**	0.25	0.28*	0.09
		(145)	(37)	(65)	(43)	(145)	(37)	(65)	(43)
	09	0.21	-0.25	0.35	0.49*	0.12	0.08	0.34	-0.1
		(82)	(25)	(28)	(29)	(84)	(25)	(29)	(30)
Age	01	0.53**	0.32*	0.59**	0.64**	0.54**	0.56**	0.52**	0.62**
		(202)	(51)	(95)	(56)	(202)	(51)	(95)	(56)
	03	0.39**	0.47*	0.48**	0.26	0.44**	0.40*	0.36*	0.63**
		(151)	(35)	(75)	(41)	(151)	(35)	(75)	(41)
	05	0.28*	0.00	0.46**	0.09	0.39**	0.26	0.47**	0.38*
		(149)	(37)	(68)	(44)	(149)	(37)	(68)	(44)
	09	0.00	-0.04	0.11	-0.20	0.25*	0.20	0.38	0.11
		(109)	(28)	(51)	(30)	(109)	(28)	(51)	(30)
Interior Wall Paint Pb, Max	01	0.00	-0.13	0.09	0.10	-0.16*	-0.07	-0.23	0.03
		(153)	(42)	(70)	(41)	(155)	(42)	(70)	(43)
	03	0.08	-0.05	0.23	0.00	0.09	-0.15	0.23	0.14
		(134)	(34)	(62)	(38)	(135)	(34)	(63)	(38)
	05	0.10	0.01	0.21	0.06	0.05	0.14	0.04	0.20
		(147)	(35)	(68)	(44)	(147)	(35)	(68)	(44)
	09	0.15	0.12	0.37*	-0.05	-0.15	0.00	-0.22	-0.12
		(107)	(28)	(50)	(29)	(108)	(28)	(51)	(29)

TABLE 4-52 (cont'd). INTERCORRELATIONS BETWEEN BLOOD LEAD AND HAND LEAD AND ENVIRONMENTAL LEAD MEASURES AND AGE
For overall study population and by area
(logarithmic)

		Blood Lead				Hand Lead			
Factor	Phase	Overall	A	B	C	Overall	A	B	C
Interior Window Dust Pb Concn.	01	0.17*	0.27	0.06	0.09	0.29*	0.35*	0.19	0.18
		(186)	(44)	(89)	(53)	(191)	(44)	(92)	(55)
	03	0.21*	0.28	-0.06	0.13	0.20*	0.00	-0.01	0.21
		(148)	(33)	(75)	(40)	(149)	(33)	(76)	(40)
	05	0.19*	0.25	0.06	0.21	0.22*	0.23	0.11	0.15
		(149)	(37)	(68)	(44)	(149)	(37)	(68)	(44)
	09	a	a	a	a	a	a	a	a
Interior Mat Dust Pb Loading	01	0.18*	0.05	0.18	0.15	0.27**	0.42*	0.18	0.15
		(188)	(45)	(90)	(53)	(193)	(45)	(93)	(55)
	03	0.14	0.06	-0.06	-0.10	0.16*	0.19	-0.17	0.07
		(148)	(32)	(75)	(41)	(149)	(32)	(76)	(41)
	05	0.32*	0.22	0.36*	0.17	0.33**	0.08	0.30*	0.24
		(145)	(37)	(64)	(44)	(145)	(37)	(64)	(44)
	09	a	a	a	a	a	a	a	a
Interior Mat Dust Pb Concn.	01	0.12	0.12	0.02	0.15	0.29**	0.46*	0.21*	0.19
		(180)	(43)	(86)	(51)	(185)	(43)	(89)	(53)
	03	0.17*	-0.02	-0.12	0.14	0.10	0.17	-0.16	-0.19
		(147)	(32)	(74)	(41)	(148)	(32)	(75)	(41)
	05	0.36**	0.25	0.29*	0.35*	0.44**	0.19	0.51**	0.27
		(137)	(35)	(59)	(43)	(137)	(35)	(59)	(43)
	09	a	a	a	a	a	a	a	a

TABLE 4-52 (cont'd). INTERCORRELATIONS BETWEEN BLOOD LEAD AND HAND LEAD AND ENVIRONMENTAL LEAD MEASURES AND AGE
For overall study population and by area
(logarithmic)

		Blood Lead				Hand Lead			
Factor	Phase	Overall	A	B	C	Overall	A	B	C
Interior Trim Paint Pb, Max	01	0.04	-0.22	0.24*	0.06	-0.08	-0.07	-0.04	-0.06
		(152)	(41)	(70)	(41)	(154)	(41)	(70)	(43)
	03	0.07	-0.06	0.27*	-0.16	0.12	-0.20	0.29*	0.12
		(133)	(33)	(62)	(38)	(134)	(33)	(63)	(38)
	05	0.13	0.00	0.29*	-0.09	0.09	-0.01	0.16	0.00
		(146)	(34)	(68)	(44)	(146)	(34)	(68)	(44)
	09	0.21*	0.29	0.36*	-0.34	0.00	-0.35	0.09	-0.05
		(107)	(28)	(50)	(29)	(108)	(28)	(51)	(29)
Exterior Wall Paint Pb	01	-0.08	-0.11	0.03	0.00	-0.17*	0.02	-0.28*	-0.24
		(133)	(37)	(64)	(32)	(133)	(37)	(64)	(32)
	03	-0.09	-0.21	0.21*	-0.38*	0.13	0.10	0.28*	-0.02
		(118)	(29)	(59)	(30)	(118)	(29)	(60)	(30)
	05	0.05	0.10	0.14	-0.13	0.08	0.22	0.04	-0.04
		(129)	(34)	(63)	(32)	(129)	(34)	(63)	(32)
	09	0.07	-0.21	0.39*	-0.14	-0.20	-0.18	-0.15	-0.25
		(89)	(24)	(45)	(20)	(90)	(24)	(46)	(20)

TABLE 4-52 (cont'd). INTERCORRELATIONS BETWEEN BLOOD LEAD AND HAND LEAD AND ENVIRONMENTAL LEAD MEASURES AND AGE
For overall study population and by area
(logarithmic)

		Blood Lead				Hand Lead			
Factor	Phase	Overall	A	B	C	Overall	A	B	C
Exterior Trim	01	-0.05	-0.16	0.14	0.02	-0.11	-0.09	-0.09	0.09
Paint Pb		(153)	(42)	(70)	(41)	(155)	(42)	(70)	(43)
	03	0.00	0.09	0.14	-0.06	0.10	-0.13	0.35*	0.12
		(134)	(34)	(62)	(38)	(135)	(34)	(63)	(38)
	05	0.04	0.41*	0.00	-0.12	0.01	0.08	-0.11	0.25
		(147)	(35)	(68)	(44)	(147)	(35)	(68)	(44)
	09	0.23*	0.47*	0.32*	-0.13	-0.13	-0.19	0.00	-0.30
		(107)	(28)	(50)	(29)	(108)	(28)	(51)	(29)

Top number is correlation coefficient. Bottom number in parentheses is number of samples.
*p ≤ 0.05.
**p ≤ 0.005.
n = no samples collected

Abatement: Interior dust abatement occurred in Areas A & B after Phase 01 and about 3 mo prior to Phase 03.
Exterior dust & soil abatement occurred in Area A after Phase 01 and about 3 mo prior to Phase 03.
Exterior dust & soil abatement occurred in Area B after Phase 05 and about 10 mo prior to Phase 09.

TABLE 4-53. SUMMARY OF BLOOD LEAD AND HAND LEAD CORRELATIONS
(Pearson Correlation Coefficients)

	Overall		Area A		Area B		Area C	
Phase	Arith.	Log	Arith.	Log	Arith.	Log	Arith.	Log
01 Coeff.	0.47	0.51	0.52	0.40	0.44	0.52	0.28	0.48
P	0.0001	0.0001	0.0001	0.004	0.0001	0.0001	0.04	0.0002
n	202	202	51	51	95	95	56	56
03 Coeff.	0.51	0.40	0.07	0.08	0.62	0.53	0.16	0.11
P	0.0001	0.0001	0.7	0.6	0.0001	0.0001	0.3	0.5
n	151	151	35	35	75	75	41	41
05 Coeff.	0.34	0.41	0.27	0.27	0.51	0.61	0.15	0.10
P	0.0001	0.0001	0.1	0.1	0.0001	0.0001	0.3	0.5
n	149	149	37	37	68	68	44	44
07 Coeff.	0.28	0.38	0.11	0.36	0.32	0.40	0.38	0.32
P	0.0018	0.0001	0.9858	0.0583	0.0116	0.0011	0.0221	0.0548
n	126	126	28	28	63	63	35	35
09 Coeff.	0.28	0.37	0.36	0.33	0.22	0.37	0.46	0.36
P	0.003	0.0001	0.06	0.08	0.1	0.008	0.01	0.05
n	109	109	28	28	51	51	30	30

in DPbDIMD; in Area "B", DPbB decreased 0.000001 mg/dL for per mg/m^2 increase in DPbDIMD; in Area "C", DPbB increased 0.000089 mg/dL for per mg/m^2 increase in DPbDIMD. Age and social-economic scores were also important factors in predicting the difference of blood lead, e.g., DPbB decreased 0.082 mg/dL for per month increase in age. DPbB decreased 0.22 mg/dL for per unit score increase in Hollingshead social economic score (SES). The initial blood lead affected the difference of blood lead between Phase 1 and Phase 5. For high initial blood lead children, DPbB was smaller than that for low initial blood lead children, e.g., DPbB decreased 0.41 mg/dL for per mg/dL increase in initial blood lead.

To investigate the effectiveness of soil lead abatement, three methods were used:

(1) correlation analysis,
(2) regression modeling, and
(3) structural equation modeling.

Two biomarkers, handwipe lead and blood lead, and two environmental exposure markers, exterior dust lead and interior dust lead, were used in the analysis. In this report, we investigated the relationships of these four markers and other variables, e.g., treatment area, paint lead, age, house age and SES.

TABLE 4-54. INTERCORRELATIONS AMONG ENVIRONMENTAL AND BLOOD LEAD DATA

	LN (PbB) µg/dL	LN (PbB) µg	LN (PbD INT) ppm	LN (PbD INT) mg/m^2	LN (XRF) mg/m^2
LN (PbH) µg	0.51^{**} (0.44)[a]				
LN (PbD INT)[a] ppm	0.18^{*} (0.41)	0.38^{**} (0.45)			
LN (PbD INT)[b] mg/m^2	0.11 (0.37)	0.32^{**} (0.36)	n.d. (0.72)		
LN (XRF)[c] mg/m^2	0.04 (0.43)	-0.08 (0.32)	0.05 (0.63)	0.09 0.51	
LN (PbD EXT)[d] ppm	0.15^{*} (0.30)	0.27^{**} (0.36)	0.42^{**} (0.60)	0.19^{*} (0.45)	-0.11 (0.49)

[a]Cincinnati Prospective Study (1981) all correlations ≤ 0.0001.
[b]floor dust values.
[c]Interior trim for Soil Project and maximum value for Prospective Study.
[d]Target exterior dust for Soil Project, exterior surface scrapings for Prospective Study.
n.d. = not determined.
$^{*}p \leq 0.05$.
$^{**}p \leq 0.0001$.

Correlation analysis was used to investigate the relationship between two variables regardless of the influences of other variables. Multiple regression analysis was used to investigate the relationship between one marker variable, e.g., blood lead, and other variables. The structural relationships between these four marker variables and other variables are ignored in the regression analysis. A structural equation model was used to investigate the structural relationship between these four marker variables, blood lead, handwipe lead, interior dust and exterior dust, and other variables simultaneously.

Note that $b = r \bullet SD(y)/SD(x)$ for any two random variables, y and x, where b is the slope of the simple regression, $y=a+bx$, and r is the correlation coefficient, $cov(x, y)/(SD[x] \bullet SD[y])$. This relationship between the correlation coefficient r and the regression slope b was used.

The findings of these analysis are:

(i) In the correlation analysis, the difference of handwipe lead between Phase 1 and Phase 5 was correlated with the difference of blood lead between Phase 1 and Phase 5 (p-value <0.1). The difference of blood lead in Area "A" was greater than that in Areas "B" and "C", e.g., DPbB in Area "A" was $0.18*5.28/0.46=2.07$ µg/dL more than that in Areas "B" and "C".

(ii) In the regression modeling, the difference of interior dust lead between Phase 1 and Phase 5 was correlated with the difference of blood lead between Phase 1 and Phase 5. The difference of blood lead between Phase 1 and Phase 5 in Area "A" was greater than that in Areas "B" and "C", e.g., DPbB in Area "A" was 2.87 mg/dL greater than that in Areas "B" and "C".

(iii) In the structural equation modeling, the difference of interior dust lead between Phase 1 and Phase 5 had a significant contribution to the difference of blood lead between Phase 1 and Phase 5. The difference of blood lead between Phase 1 and Phase 5 in Area "A" was greater than that in Area "C", e.g., DPbB in Area "A" was 2.13 mg/dL greater than that in Area "C".

4.11.1.1 Correlation Analysis

To investigate the trends of these four markers, we used the difference of each marker between Phase 1 and Phase 5 as a new marker. This positive value for the new marker indicated that the value of the corresponding original marker was an increase from Phase 1 to Phase 5, and vice versa.

For the data collected in Phase 1 and Phase 5, calculations were made of the difference in blood lead(DPbB), the difference in handwipe lead(DPbH), the difference in the median interior dust lead loading(DPbDIMD) and the difference in the median exterior dust lead loading(DPbDELD) between Phase 1 and Phase 5 respectively. Thus,

DPbB=PbB(5) - PbB(1),

DPbH=PbH(5)-PbH(1),

DPbDIMD=PbDIMD(5)-PbDIMD(1), and

DPbDELD=PbDELD(5)-PbDELD(1).

The variables included in this data analysis are listed below:

DPbB(mg/dL): difference of blood lead between Phase 1 and 5,

DPbH(mg): difference of handwipe lead between Phase 1 and 5,

AGE_M5(month): age at Phase 5,

AGE_MS5(month^2): square of age at Phase 5,

AGE_MH5(month): age at Phase 5 for handwipe,

AGE_MHS5(month^2): square of age at Phase 5 for handwipe,

DPbDIFL(μg/m^2): difference in interior floor dust lead loading between Phase 1 and 5,

DPbDELD(mg/m^2): difference of median exterior dust lead loading between Phase 1 and Phase 5,

PbDELD1(mg/m^2): median of exterior dust lead loading at Phase 1,

PbB1(mg/dL): blood lead at Phase 1,

PbH1(mg): handwipe lead at Phase 1,

PbDIMD1(μg/m^2): median of interior dust lead loading at Phase 1,

PbPITMN(mg/cm^2): mean of interior paint trim lead,

PbPET(mg/cm^2): exterior paint trim lead,

PbP(mg/cm^2): paint lead,

PNT: paint lead be removed or not (1=yes, 0=no),

PNT_NR: paint lead be removed from nearby building or not (1=yes, 2=no),

JOB: household job related to lead (1=yes, 2=no),

ACT: activities in the home related to lead (1=yes, 2=no),

WORK5 (numeric): a composite score of JOB, ACT, PNT and PNT_NR at Phase 5, [PNT: paint was removed from apartment building or not (1=yes. 0=no), PNT_NR: paint lead was removed from nearby building or not (1=yes, 0=no), JOB: member of household had job related to lead (1=yes, 0=no), ACT: activities in the home related to lead (1=yes, 0=no).],

A: Area A (interior and exterior dust lead were abated),

B: Area B (interior dust lead was abated),

C: Area C (no abatement),

SES: Hollingshead social-economic score.

The summary results from correlation analysis are shown in the following six tables. Summary statistics are shown in Table 4-55. Summary statistics for DPbB, DPbH, DPbIFL, and DPbELD by area are shown in Table 4-56. The Pearson correlation between DPbB and the other important variables are shown in Table 4-57. The correlations between DPbH and the other important variables are presented in Table 4-58. The correlations between DPbDIFL and the other important variables are presented in Table 4-59. The correlations between DPbDELD and the other important variables are listed in Table 4-60.

From Table 4-56, we can draw following conclusions:

(1) DPbB and DPbH were higher in Area "A" than that in Areas "B" and "C"; ie., the mean of PbB increased from Phase 1 to Phase 5 in Area "A"; the mean of PbB decreased from Phase 1 to Phase 5 in Areas "B" and "C". The mean of handwipe lead increased from Phase 1 to Phase 5 in all areas.

TABLE 4-55. SUMMARY STATISTICS

Variable	Number	Mean	SD
DpbB	148	−0.64	5.28
DpbH	119	3.99	18.29
AGE_M5	148	42.52	17.76
AGE_MS5	148	2120.86	1574.39
AGE_MH5	126	43.11	17.66
AGE_MHS5	126	2168.57	1578.09
DPbDIFL	128	−17.30	1193.0
DPbDELD	127	97489	615021
PbDELD1	138	368077	635934
PbH1	136	10.18	12.94
PbB1	148	10.50	5.13
PbDIFL1	138	411.62	910.66
PNT	148	0.27	0.45
PNT_NR	148	1.75	0.43
PBP	148	2.05	2.22
WORK5	148	0.17	0.21
H_AGE	148	110.16	16.84
SES	148	19.47	7.31
A	43	0.29	0.46
B	61	0.41	0.49
C	44	0.30	0.46

Note: A=1 for Area A, A=0 for other areas; B=1 for Area B, B=0 for other areas; C=1 for Area C, C=0 for other areas.

(2) DPbDIFL was smaller in Area "A" than that in Area "B" and "C"; i.e., interior dust lead decreased from Phase 1 to Phase 5 in Area "A"; however it increased from Phase 1 to Phase 5 in Areas "B" and "C".

(3) Exterior dust lead increased in all areas. But it increased more rapidly in Area "B" than in Areas "A" and "C".

TABLE 4-56. SUMMARY STATISTICS OF DPbB, DPbH, DPbDIFL, AND DPbDELD BY AREA

	DPbB		DPbH		DPbDIFL		DPbDELD	
Area	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
A	0.87	5.60	9.10	25.23	−451.13	1288.84	119280.1	308629.2
B	−1.51	5.17	2.55	17.24	181.77	1437.75	164066.3	922978.1
C	−0.91	4.90	1.70	11.10	51.06	427.79	71.77	223152.8

4.11.1.2 Regression Modeling

The results of correlation analysis presented in the previous section have one drawback. The correlation coefficient computed between any two random variables were not adjusted by other covariates, e.g., environmental variables. This can be improved by regression.

The multiple regression was used to fit the following four regression models of DPbB, DPbH, DPbDIMD and DPbDELD. The initial models are given below.

DPbB = A+B+DPbH+ DPbDIMD +DPbDELD+AGE_M5+AGE_MS5+ +PbB1+SES+WORK5+PNT+PbP+PNT_NR+H_AGE + A* DPbDIMD + A*DPbDELD+B*DPbDIMD + B*DPbDELD,

4.11.1.3 Multiple Regression Modeling

Multiple regression was used to fit the following four regression models of DPbB, DPbH, DPbDIFL and DPbDELD. The initial models are given below:

DPbB = A+B+DPbH+DPbIFL+DPbDELD+AGE_MH5+PbB1+SES +WORK5+PbP+H_AGE

DPbH = A+B+DPbDIMD+DPbDELD+AGE_MH5+AGE_MHS5+ PbH1+SES+WORK5+PbP+PNT+H_AGE+PNT_NR +A*DPbDIMD+A*DPbDELD+B*DPbDIMD+ B*DPbDELD,

DPbDIMD = A+B+DPbDELD+SES+PNT+PbP+PbDIMD1+PNT_NR+ +H_AGE+A*DPbDELD+B*DPbDELD,

DPbDELD = A+B+PbDELD1+SES+PNT_NR+PNT+PbP+H_AGE.

TABLE 4-57. CORRELATIONS BETWEEN BLOOD LEAD AND OTHER IMPORTANT VARIABLES

Variable	Number	Corre. Coef	P-value
DPbH*	119	0.15	0.099
AGE_M5*	148	−0.37	0.0001
AGE_MS5*	148	−0.33	0.0001
DPbDIFL	128	−0.02	0.80
DPbDELD	127	−0.08	0.37
A*	43	0.18	0.025
B*	61	−0.14	0.09
C	44	−0.03	0.69
PbH1*	136	−0.15	0.08
PbB1*	148	−0.46	0.0001
PbDIMD1*	138	−0.16	0.055
PbDELD1	138	0.04	0.63
PNT	148	0.09	0.28
PNT_NR	148	−0.12	0.15
P BP	148	−0.05	0.53
H_AGE	148	0.056	0.50
WORK5	148	0.092	0.27
SES*	108	−0.18	0.07

*Denotes variables significantly correlated (alpha ≤ 0.1) with DPbB.

The following conclusions can be derived from the Table 4-57:

(1) the change in handwipe lead affected the change in blood lead. The less change in handwipe lead, the less change in blood lead. In other words, DPbB will increase 0.15*5.28/18.29 = 0.04 mg/dL for per mg increase in DPbH because corr(DPbB, DPbH) = 0.15;

(2) the child age factor affects the difference of blood lead between Phase 1 and Phase 5. For older children, the difference in blood lead between Phase 1 and Phase 5 was smaller than that for younger children. In other words, DPbB decreased 0.37*5.28/17.76 = 0.11 mg/dL for per month increase in age because corr(DPbB, AGE_M5) = -0.37;

(3) treatment (Area) affected the difference of blood lead between Phase 1 and Phase 5. In Area "A", the difference of blood lead between Phase 1 and Phase 5 was greater than that in Areas "B" and "C". In other words, DPbB has 0.18*5.28/0.46 = 2.07 mg/dL more in Area "A" than that in Areas "B" and "C";

(4) the initial (Phase 1) blood lead affected the difference of blood lead between Phase 1 and Phase 5. For the high initial blood lead children, the difference of blood lead between Phase 1 and Phase 5 was smaller than that for the low initial blood lead children. In other words, DPbB decreased 0.46*5.28/5.13 = 0.47 mg/dL for per mg/dL increase in PbB1 because corr(DPbB, PbB1) = -0.46.

TABLE 4-58. CORRELATIONS BETWEEN HAND LEAD AND OTHER IMPORTANT VARIABLES

Variable	Number	Corre. Coef.	P-value
AGE_MH5	116	−0.008	0.93
AG E_MHS5	116	0.023	0.81
DPbDIFL	108	−0.17	0.087
DPbDELD	105	0.09	0.35
PNT	119	0.08	0.40
PNT_NR	119	−0.07	0.46
PBP	119	0.087	0.34
WORK5	119	0.09	0.32
H_AGE	119	0.08	0.37
A*	31	0.17	0.07
B	51	−0.07	0. 46
C	37	−0.08	0.36
PbH1*	119	−0.40	0.0001
PbB1	119	−0.026	0.77
Pb DIMD1	109	0.045	0.64
PbDELD1	112	0.07	0.46
SES	119	−0.08	0.36

In the above table, the variable marked with "*" are significantly correlated with DPbH.

From Table 4-58, the following conclusions are evident:

(1) The initial (Phase 1) handwipe lead affected the difference of handwipe lead between Phase 1 and Phase 5 (DPbH). For children with high initial handwipe lead, the difference of handwipe lead between Phase 1 and Phase 5 was smaller than that for the low initial handwipe lead children. In other words, DPbH decreased 0.40*18.29/12.94 = 0.57 mg for per mg increase in PbH1 because corr(DPbH, PbH1 = -0.40.

(2) The area factor affected the difference of handwipe lead between Phase 1 and Phase 5. In Area "A", the difference of handwipe lead between Phase 1 and Phase 5 was larger than that in Areas "B" and "C". In other words, DPbH was 0.17*18.29/0.46 = 6.76 mg more in Area "A" than that in Areas "B" and "C" because corr(DPbH, A) = 0.17.

TABLE 4-59. CORRELATIONS BETWEEN DPbDIFL AND OTHER IMPORTANT VARIABLES

Variable	Number	Corre. Coef.	P-value
DPbDELD	114	−0.02	0.83
PbDELD1	119	−0.06	0.54
PbP	128	0.02	0.81
WORK5	128	−0.03	0.74
A*	32	−0.21	0.017
B*	56	0.15	0.096
C	40	0.04	0.66
PbDIFL1*	128	−0.52	0.0001
SES	128	−0.007	0.93

*Denotes variables significantly correlated (alpha ≤ 0.1) with DPbB.

The following conclusions can be derived from Table 4-59:

(1) Treatment (Area) affected the difference in interior floor dust lead between Phase 1 and Phase 5. In Area "A", the difference in interior floor dust lead between Phase 1 and Phase 5 was less than that in Areas "B" and "C". In Area "B", the difference in interior floor dust lead was greater than that in Areas "A" and "C". In other words, DPbDIFL was 0.21*1193/0.46=544.63 $\mu g/m^2$ less in Area "A" than that in Areas "B" and "C"; DPbDIFL was 0.15*1193/0.49=365.20 $\mu g/m^2$ greater in Area "B" than that in Areas "A" and "C".

(2) The initial (Phase 1) interior floor dust lead affected the difference in interior floor dust lead between Phase 1 and Phase 5. In the higher initial interior floor dust lead area, the difference in interior floor dust lead between Phase 1 and Phase 5 was smaller than that in the lower initial interior floor dust lead area. In other words, DPbDIFL decreased 0.52*1193/910.66=0.68 $\mu g/m^2$ for per $\mu g/m^2$ increase in PbDIFL1 because corr(DPbDIFL, PbDIFL1)= −0.52.

The summaries of backward elimination procedures for these regression equations is given below.

For DPbB,

step 1 AGE_M5 is eliminated with p-value=0.97;
step 2 DPbDELD is eliminated with p-value=0.85;
step 3 PbP is eliminated with p-value=0.65;
step 4 H_AGE is eliminated with p-value=0.62;
step 5 DPbDIFL is eliminated with p-value=0.43;
step 6 WORK5 is eliminated with p-value=0.33;
step 7 B is eliminated with p-value=0.17;
step 8 A is eliminated with p-value=0.16.

TABLE 4-60. CORRELATIONS BETWEEN EXTERIOR DUST LEAD AND OTHER IMPORTANT VARIABLES

Variable	Number	Corre. Coef.	P-value
SES*	127	0.17	0.05
PbDELD1*	127	-0.31	0.0004
PBP	127	0.03	0.74
H_AGE	127	0.07	0.41
WORK5	127	-0.12	0.17
A	35	0.02	0.81
B	50	0.087	0.33
C	42	-0.11	0.21

In the above table, DPbDELD was highly correlated with PbDELD1, SES and PNT_NR.
From Table 4-59, the following conclusions can be made:

(1) The initial (Phase 1) exterior dust lead affected the difference of exterior dust lead between Phase 1 and Phase 5 (DPbDELD). For the high initial exterior dust lead area, the difference of exterior dust between Phase 1 and Phase 5 was greater than that in the low initial exterior dust lead area. In other words, DPbDELD decreased 0.31*615021/635934 = 0.30 mg/m^2 for per mg/m^2 increase in PbDELD1 because corr(DPbDELD, PbDELD1) = -0.31.

(2) The social-economic status affected the difference of exterior dust lead between Phase 1 and Phase 5. In the higher SES families, the difference of exterior dust lead between Phase 1 and Phase 5 was greater than in the low SES family. In other words, DPbDELD increased 0.17*615021/7.31 = 14302.8 mg/m^2 for per SES unit increased because corr(DPbDELD, SES) = 0.17.

For DPbH,

step 1 H_AGE is eliminated with p-value=0.87;
step 2 PbP is eliminated with p-value=0.81;
step 3 DPbDELD is eliminated with p-value=0.52;
step 4 WORK5 is eliminated with p-value=0.40;
step 5 SES is eliminated with p-value=0.36;
step 6 AGE_MH5 is eliminated with p-value=0.28;
step 7 DPbDIFL is eliminated with p-value=0.22;
step 8 B is eliminated with p-value=0.15;
step 9 A is eliminated with p-value=0.12.
step 10 AGE_MHS5 is eliminated with p-value=0.11.

For DPbDIFL,

step 1 SES is eliminated with p-value=0.95;
step 2 PbP is eliminated with p-value=0.93;
step 3 DPbDELD is eliminated with p-value=0.89;
step 4 WORK5 is eliminated with p-value=0.87;
step 5 A is eliminated with p-value=0.76;
step 6 H_AGE is eliminated with p-value=0.37.

For DPbDELD,

step 1 PbP is eliminated with p-value=0.43;
step 2 A is eliminated with p-value=0.47;
step 3 H_AGE is eliminated with p-value=0.12.

After the backward eliminations, four final regression models remained:

Model 1 DPbB = 8.52 + 0.038 DPbH − 0.00079AGE_MS5 − 0.17 SES − 0.43 PbBl,
Model 2 DPbH = 9.38 − 0.50 PbHl,
Model 3 DPbDIFL = 169.05 + 297.89 B − 0.91 PbDIFLl,
Model 4 DPbDELD = −228137.95 + 13290.31 SES + 316397.88 B + 481704.88 WORK5 − 0.35 PbDELDl.

From the final models the following conclusions were made:

(1) The change of the difference in handwipe lead between Phase 1 and Phase 5 (DPbH) affected the change of the difference in blood lead. In other words, blood lead decreased 0.038 μg/dL for per μg/dL decrease in handwipe (see Model 1).

(2) Age, SES, and PbBl were important factors to interprete the difference of blood lead. For the children with high SES (>30 unit scores) and moderate high PbBl (>18 μg/dL), the blood lead would decrease from Phase 1 to Phase 5. The older these children were, the more rapidly their blood lead decreased from Phase 1 to Phase 5 (see Model 1).

(3) The difference in handwipe lead between Phase 1 and Phase 5 was reversely proportional to the initial handwipe lead. For the higher initial handwipe lead children (PbHl >19 μg), their handwipe lead decreased from Phase 1 to Phase 5 (see Model 2).

(4) The differences in interior floor dust lead were different in different areas. In Area "B" where the initial interior floor dust lead was higher than 515 $\mu g/m^2$, the interior floor dust lead loading decreased from

Phase 1 to Phase 5. However, in Areas "A" and "C" where the initial interior floor dust lead loading was higher than 186 $\mu g/m^2$, the interior floor dust lead loading decreased from Phase 1 to Phase 5 (see Model 3).

(5) The differences in exterior dust lead were different in different areas. In Area "A" and "C" where household activities were not related to lead and the initial exterior dust lead loading was moderate high (PbDELD > 870,000 $\mu g/m^2$), the exterior dust lead loading decreased from Phase 1 to Phase 5. In Area "B" where household activities were not related lead and the initial exterior dust lead loading was higher than 1,770,000 $\mu g/m^2$, the exterior dust lead loading would decrease from Phase 1 to Phase 5.

4.11.1.4 Structural Equation Modeling

The four dependent variables DPbB, DPbH, DPbDIMD and DPbDELD were mutually correlated. The regression models shown above do not account for this fact since they were fitted individually. When the equations in a system are interdependent, e.g., the response variable in one equation appears as the regressors in other equation, the ordinary least square estimates of the parameters in the system may be inconsistent. To solve this, we fit these four models simultaneously by a system of linear equations.

We re-analyzed the above models as a system of simultaneous linear equations, using SAS SYSLIN. The initial models here are similar to the initial regression models in Section 2.

The final models were:

DPbB = 10.28 − 0.18 SES − 0.064 AGE_M5 − 0.46 PbBl,
DPbH = 5.78 + 0.002 AGE_MH5 − 0.62 PbH1,
DPbDIMD = 291.87 − 0.91 PbDIFLl,
DPbDELD = 273191B.

The final structural models are shown in Figure 4-29.

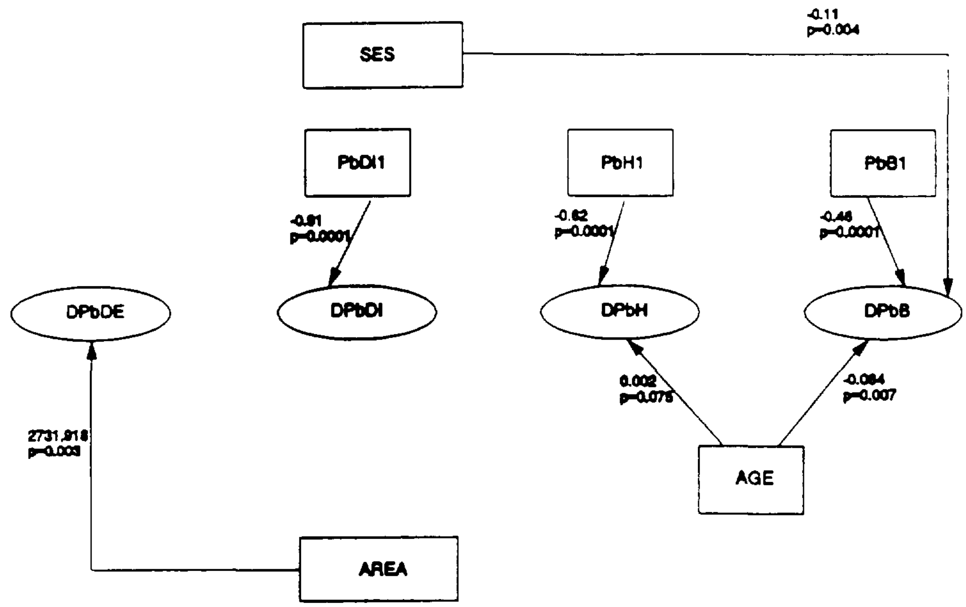


Figure 4-29. Structural equation analysis: relationship between blood lead and environmental lead.

From the final SYSLIN models, the following conclusions are drawn:

(1) In the DPbB model, SES, AGE, and PbBl were important factors to predict the difference of blood lead between Phase 1 and Phase 5. For children with high SES (>30 unit scores) and moderate high PbBl (>10 μg/dL), their blood lead would decrease from Phase 1 to Phase 5. The older the children, the more rapidly their blood lead decreased from Phase 1 to Phase 5.

(2) In the DPbH model, the initial handwipe lead affected the difference in handwipe lead between Phase 1 and Phase 5. For moderate high initial handwipe lead children (PbHl >26 μg), the handwipe lead decreased from Phase 1 to Phase 5.

(3) In the DPbDIFL model, the initial interior floor dust lead affected the difference in interior floor dust lead between Phase 1 and Phase 5. In the area with higher initial interior floor dust lead (PbDIFLl >325 μg/m^2), the interior floor dust lead loading decreased from Phase 1 to Phase 5.

(4) In the DPbDELD model, area factor affected the difference in exterior dust lead between Phase 1 and Phase 5. In area "B", the exterior dust lead loading increased by 273191 $\mu g/m^2$ from Phase 1 to Phase 5; and the exterior dust lead did not change significantly in Areas "A" and "C" from Phase 1 to Phase 5.

4.11.1.5 Comparisons of Treatment-Effects Among the Three Statistical Approaches

The treatment-effect comparisons from these three methods were as follows:

To use the correlation analysis to compare the treatment effects across areas, we rely on the fact that the $b=r*SD(y)/SD(x)$, where b is the coefficient of simple regression $y=\mu+bx$, r is the correlation coefficient between x and y. The positive value of r will give the positive value of b which indicated that y significantly increased as x increased.

Correlation analysis

DPbB was significantly greater in Area "A" than that in either Area "B" or "C".

DPbH was significantly greater in Area "A" than that in either Area "B" or "C".

DPbDIFL was significantly greater in Area "B" than that in either Area "A" or "C".

DPbDELD was not significantly different between areas.

Multiple regression analysis

DPbB was not significantly different between areas.

DPbH was not significantly different between areas.

DPbDIFL was significantly greater in Area "B" than that in either Area "A" or "C".

DPbDELD was significantly greater in Area "B" than that in either Area "A" or "C".

Structural equation analysis

DPbB was not significantly different between areas.

DPbH was not significantly different between areas.

DPbDIFL was not significantly different between areas.

DPbDELD was significantly greater in Area "B" than that in either Area "A" or "C".

From the above results, the following conclusions were made:

(1) The difference in blood lead between Phase 1 and Phase 5 in Area "A" was significantly greater than that in Areas "B" and "C" by correlation analysis; however, it was not significantly different across areas by the other two methods. Also, the difference in handwipe lead in Area "A" was significantly greater than that in Areas "B" and "C" by correlation analysis; however, it was not significantly different across areas by the other two methods.

(2) The difference in interior dust between Phase 1 and Phase 5 was significantly greater in Area "B" than that in Areas "A" and "C" by correlation and regression analysis; however it was not significantly different across all areas by the structural equation method.

(3) The difference in exterior dust between Phase 1 and Phase 5 was significantly greater in Area "B" than that in Areas "A" and "C" by structural and regression analysis; however, it was not significantly different across Areas "A", "B", and "C" by correlation method.

(4) Since the SYSLIN method is superior to the other two methods in terms of investigating their structural relationship, the results from SYSLIN were thought to be more reliable.

4.11.1.6 Statistical Modeling Conclusions

In this study, the differences in blood lead, handwipe lead, and interior dust lead were not significantly different across all areas. Age, initial blood lead, and socio-economic score were the important factors in the prediction of the change in blood lead. In other words, DPbB decreased 0.064 μg/dL for per month increase in AGE; DPbB decreased 0.46 μg/dL for per μg/dL increased in PbB1. DPbB decreased 0.18 μg/dL for per unit score increase in Hollingshead social economic score (SES). From structural equation analysis, we found that for the children with higher SES scores (> 30 units) and moderate high PbB1 (> 10 μg/dL), their blood lead decreased from Phase 1 to Phase 5. The older these children were, the more rapidly their blood lead decreased from Phase 1 to Phase 5. For children with moderate high initial handwipe lead (> 26 μg), their handwipe lead decreased from

Phase 1 to Phase 5. For lower initial handwipe lead (< 9 μg) children, their handwipe lead increased from Phase 1 to Phase 5. The older these children were, the more rapidly their handwipe lead increased from Phase 1 to Phase 5. In the areas where the initial interior floor dust lead loading was higher than 325 $\mu g/m^2$, the interior floor dust lead loading decreased from Phase 1 to Phase 5. Exterior dust lead loading increased by 273,000 $\mu g/m^2$ in Area "B" from Phase 1 to Phase 5, but it did not change significantly in Areas "A" and "C".

4.11.2 Cross-Sectional Structural Equation Models for Loading Data

Measurements were made on different sampling units during the soil abatement project. Blood lead (PbB) and hand lead (PbH) were measured on individual children; interior dust lead (PbD) and paint XRF_{int}) on individual apartments; and exterior paint (XRF_{ext}) and exterior dust lead on individual buildings and nearby paved areas. Analyses of these data must take into account these design features, to avoid inflation of the degrees of freedom for testing important effects and biased estimates of the postulated relationships.

Structural equation models including variables which quantify the nested design were used to explore the relationships among the environmental data, each expressed as loadings, and the outcomes of PbB and PbH. Each equation included indicator variables for different buildings. The interior PbD and XRF, and PbH and PbB equations also included terms for different apartments (within buildings); and the PbH and PbB equations also included terms for different siblings (within apartments). Interaction terms, between the mediating endogenous variables and these nested factors were created wherever possible. These interactions, if significant, served as error terms for testing the endogenous variables' effect. For example, a PbH* family interaction was introduced into the PbB model to test the significance of PbH's effect on PbB. In all models, buildings variance served as the error term for testing the effects of Abatement Area and Neighborhood (within areas).

Each of the endogenous variables were initially entered into equations further in the postulated "casual chain" (Exterior Measurements -> Interior Measurements (PbD_{window}), PbD_{entry}) -> PbD_{floor}) -> PbH -> PbB. The covariates of housing type and age, 4 behavioral variables [JOB, ACT, PAINT and $PAINT_{neighborhood}$]* were entered into each structural equation).* Race, sex, child's age and SES were entered into the PbH and PbB models; mouthing behavior was used in the PbB model only. A number of interactions were also considered. Abatement area, age and mouthing was interacted with each environmental Pb variable in every model in which both of these main effects were initially used.

A strategy of backward elimination of insignificant effects was followed. Interactions were removed before main effects and only terms compared directly to error were candidates for removal.

Multiple imputation of any missing endogenous variables' data was performed. Any bias due to imputation was removed from the model by introducing indicator variables for these imputed data points into the structural model.

The final models are shown in Tables 4-61 through 4-63 and Figures 4-30 through 4-32.

*JOB = job in an industry where lead may be used.

ACT = hobby or other activity which may use lead.

PAINT = painting in apartment or building within past six months.

$PAINT_{NEIGH}$ = painting in neighborhood within past six months.

4.11.2.1 Summary and Conclusions from the Cross-Sectional Structural Equation Models

The preabatement model shows no effect of environmental lead loadings on PbB and PbH (Figure 4-30). This may partly explain the difficulty that was encountered by this study in attempting to significantly reduce these indices of exposure.

The postabatement models (Figures 4-31 and 4-32) appear to show both a pattern of recontamination and differential effects by abatement areas. Different distal sources of lead may be acting in each abatement area. These cross-sectional models are a prelude to even more detailed and complex longitudinal models. We plan to use these results to help us model the changes in PbB, PbH, and PbD over the course of the project.

TABLE 4-61. RESULTS OF STRUCTURAL EQUATIONS MODELING USING PHASE 1 LEAD LOADING DATA

Exogenous (Phase 1)	Estimate	t of F	p
Dependent: ln (PbB)			
Intercept	1.375	—	—
ln (PbH)	0.093	2.13	0.02*
Age	0.046	6.81	0.0001
Age*Age	-0.0006	-5.78	0 0001
Mouthing	0.217	2.45	0.008*
Areas		$F(2, 87) = 0.17$	0.85
A	0.044		
B	-0.137		
Neighborhoods		$F(3, 87) = 0.50$	0.68
B	-0.040		
D	0.251		
G	-0.050		
Families		$F(87, 1{,}019) = 1.70$	0.0001
Dependent: ln (PbH)			
Intercept	0.720	—	—
Age	0.069	6.13	0.0001
Age*Age	-0.0007	-4.15	0.0001
Areas		$F(2, 83) = 0.04$	0.96
A	0.188		
B	0.175		
Neighborhoods		$F(3, 83) = 0.33$	0.80
B	0.353		
D	0.012		
G	-0.472		
Families		$F(83, 1{,}019) = 2.19$	0.0001
Dependent: ln (PbD_{floor})			
Intercept	3.718	—	—
ln (PbD_{window})	0.097	2.07	0.02*
ln (PbD_{entry})	0.134	3.43	0.0001*
Areas		$F(2, 79) = 0.02$	0.98
A	0.263		
B	0.299		
Neighborhoods		$F(3, 79) = 0.37$	0.77
B	-0.610		
D	-0.834		
G	-1.018		
Apartments		$F(79, 1{,}019) = 5.14$	0.0001

TABLE 4-61 (cont'd). RESULTS OF STRUCTURAL EQUATIONS MODELING USING PHASE 1 LEAD LOADING DATA

Exogenous (Phase 1)	Estimate	t of F	p
Dependent: ln (PbD_{window})			
Intercept	5.968	—	—
House Type	1.175	2.47	0.008*
Areas		F (2, 78) = 0.58	0.56
A	2.253		
B	-0.502		
Neighborhoods		F (3, 78) = 0.37	0.77
B	0.090		
D	1.478		
G	1.816		
Apartments		F (78, 1,019) = 8.96	0.0001
Dependent: ln (PbD_{entry})			
Intercept	24.067	—	—
ln (PbD_{ext})	-1.637	-4.80	0.0001*
House Type	1.836	3.86	0.0001*
Areas		F (2, 79) = 1.11	0.33
A	-23.581		
B	-20.238		
Neighborhoods		F (3, 79) = 0.12	0.95
B	-0.695		
D	-0.085		
G	-1.350		
Areas* ln (PbD_{ext})		F (2, 1,019) = 10.28	0.0001
A* ln (PbD_{ext})	1.947		
B* ln (PbD_{ext})	1.588		
Apartments		F (79, 1,019) = 8.53	0.0001
Dependent: ln (PbD_{ext})			
Intercept	12.915	—	—
Paint	0.272	2.69	0.004*
Areas		F (2, 49) = 0.74	0.48
A	0.010		
B	-1.829		
Neighborhoods		F (3, 49) = 1.07	0.37
B	1.852		
D	2.291		
G	-1.237		
Dwellings		F (16, 1,019) = 20.22	0.0001

TABLE 4-61 (cont'd). RESULTS OF STRUCTURAL EQUATIONS MODELING USING PHASE 1 LEAD LOADING DATA

Exogenous (Phase 1)	Estimate	t of F	p
Dependent: ln (XRF_{int})			
Intercept	1.086	—	—
Areas		$F(2, 73) = 0.25$	0.78
A	-0.244		
B	-0.335		
Neighborhoods		$F(3, 73) = 0.44$	0.72
B	-0.187		
D	0.223		
G	0.243		
Apartments		$F(73, 1{,}019) = 2.57$	0.0001
Dependent: ln (XRF_{ext})			
Intercept	0.843	—	—
Paint	0.146	2.11	0.02*
Areas		$F(2, 45) = 0.09$	0.92
A	-0.282		
B	-0.095		
Neighborhoods		$F(3, 45) = 0.09$	0.97
B	-0.011		
D	0.222		
G	-0.021		
Dwellings		$F(45, 1{,}019) = 6.16$	0.0001

4.12 PAINT AND WATER LEAD

Paint and water sampling was conducted once for each housing unit in the study. Results of the paint lead determinations, by in situ XRF, shown in Table 4-64, reveal that the geometric mean of the maximum values for interior and exterior trim and walls ranged from 0.3 to 1.3 mg Pb/cm^2 and did not vary significantly from area to area. The geometric mean water lead concentration in 30 min stagnation samples ranged from 1.7 to 2.2 μg Pb/L (Table 4-65). The maximum value was 13.6 μg Pb/L.

TABLE 4-62. RESULTS OF STRUCTURAL EQUATIONS MODELING USING PHASE 3 LEAD CONCENTRATION DATA

Exogenous (Phase 3)	Estimate	t of F	p
Dependent: ln (PbB)			
Intercept	1.639	—	—
ln (PbB)	0.119	F (1, 42) = 1.70	0.20*
Age	0.044	5.63	0.0001
Age*Age	-0.0005	-5.04	0.0001
Areas* ln (PbH)		F (2, 42) = 1.69	0.20
A* ln (PbH)	-0.306		
B* ln (PbH)	-0.048		
Families* ln (PbH)		F (42, 960) = 1.52	0.02
Areas		F (2, 79) = 0.48	0.68
A	0.180		
B	-0.203		
Neighborhoods		F (3, 79) = 1.73	0.17
B	-0.093		
D	0.379		
G	-0.338		
Families		F (79, 960) = 0.92	0.63
Dependent: ln (PbH)			
Intercept	-1.253	—	—
ln (PbD_{window})	0.119	1.88	0.03*
ln (XRF_{int})	0.291	2.13	0.02*
Age	0.072	3.88	0.0002
Age*Age	-0.0005	-2.72	0.008
Job	0.735	2.15	0.02*
Age* ln (PbD_{window})	-0.004	2.18	0.03
Areas		F (2, 60) = 4.30	0.02
A	0.870		
B	1.555		
Neighborhoods		F (3, 60) = 0.36	0.78
B	-0.236		
D	-0.379		
G	0.349		
Apartments		F (60, 960) = 1.46	0.01

TABLE 4-62 (cont'd). RESULTS OF STRUCTURAL EQUATIONS MODELING USING PHASE 3 LEAD CONCENTRATION DATA

Exogenous (Phase 3)	Estimate	t of F	p
Dependent: ln (PbD_{floor})			
Intercept	3.992	—	—
ln (PbD_{entry})	0.301	6.82	0.0001*
Areas		$F (2, 70) = 1.09$	0.34
A	-1.527		
B	-0.422		
Neighborhoods		$F (3, 70) = 2.16$	0.10
B	-1.046		
D	-0.978		
G	-1.899		
Apartments		$F (70, 960) = 8.92$	0.0001
Dependent: ln (PbD_{window})			
Intercept	-0.039	—	—
ln (PbD_{ext})	0.475	3.36	0.006*
ln (XRF_{int})	0.918	4.79	0.0001*
Areas		$F (2, 70) = 1.77$	0.18
A	-2.907		
B	0.201		
Neighborhoods		$F (3, 70) = 0.48$	0.70
B	-0.563		
D	-1.372		
G	-0.565		
Apartments		$F (70, 960) = 4.63$	0.0001
Dependent: ln (PbD_{entry})			
Intercept	2.540	-	-
ln (XRF_{ext})	0.017	0.05	0.48*
House Type	1.882	4.41	0.0001*
Areas* ln (XRF_{ext})		$F (2, 960) = 4.20$	0.02
A* ln (XRF_{ext})	-2.650		
B* ln (XRF_{ext})	-0.588		
Areas		$F (2, 70) = 0.40$	0.67
A	1.544		
B	-0.110		
Neighborhoods		$F (3, 70) = 0.68$	0.57
B	0.981		
D	1.661		
G	0.308		
Apartments		$F (70, 960) = 5.60$	0.0001

TABLE 4-62 (cont'd). RESULTS OF STRUCTURAL EQUATIONS MODELING USING PHASE 3 LEAD CONCENTRATION DATA

Exogenous (Phase 3)	Estimate	t of F	p
Dependent: ln (PbD_{mat})			
Intercept	6.089	—	—
Areas		$F(2, 68) = 1.02$	0.37
A	-1.099		
B	0.022		
Neighborhoods		$F(3, 68) = 2.17$	0.12
B	-0.861		
D	-0.105		
G	-1.532		
Apartments		$F(68, 960) = 5.64$	0.0001
Dependent: ln (PbD_{ext})			
Intercept	10.924	—	—
House Type	1.288	7.09	0.0001*
Areas		$F(2, 40) = 0.12$	0.89
A	0.496		
B	0.612		
Neighborhoods		$F(3, 40) = 0.46$	0.71
B	0.818		
D	0.638		
G	-1.087		
Dwellings		$F(40, 960) = 22.57$	0.0001
Dependent: ln (XRF_{int})			
Intercept	1.001	—	—
Areas		$F(2, 70) = 0.25$	0.78
A	-0.159		
B	-0.307		
Neighborhoods		$F(3, 70) = 0.82$	0.49
B	-0.114		
D	0.396		
G	0.304		
Apartments		$F(70, 960) = 2.68$	0.0001
Dependent: ln (XRF_{ext})			
Intercept	0.733	—	—
House Type		$F(2, 44) = 0.06$	0.94
Areas	-0.172		
A	0.026		
B		$F(3, 44) = 0.09$	0.97
Neighborhoods	0.026		
B	0.191		
D	1.156		
G		$F(44, 960) = 5.62$	0.0001
Dwellings			

TABLE 4-63. RESULTS OF STRUCTURAL EQUATIONS MODELING USING PHASE 5 LEAD LOADING DATA

Exogenous (Phase 3)	Estimate	t of F	p
Dependent: ln (PbB)			
Intercept	11.295	—	—
ln (PbH)	0.121	1.43	0.08*
ln (PbD_{floor})	-0.400	-3.58	0.99*
ln (PbD_{entry})	-0.086	-1.19	0.12*
ln (PbD_{ext})	-0.564	-2.47	0.99*
Mouthing	-0.485	-1.66	0.95*
Paint	0.455	2.21	0.02*
Areas* ln (PbH)		F (2, 874) = 6.23	0.002
A* ln (PbH)	-0.141		
B* ln (PbH)	0.260		
Areas* ln (PbD_{floor})		F (2, 874) = 8.75	0.0002
A* ln (PbD_{floor})	0.409		
B* ln (PbD_{floor})	0.505		
Mouthing* ln (PbD_{entry})	0.097	2.19	0.02*
Areas* ln (PbD_{ext})		F (2, 874) = 3.19	0.04
A* ln (PbD_{ext})	0.853		
B* ln (PbD_{ext})	0.404		
Areas		F (2, 65) = 1.83	0.17
A	-12.955		
B	-8.326		
Neighborhoods		F (3, 65) = 0.637	0.59
B	0.002		
D	0.367		
G	-0.972		
Families		F (65, 874) = 2.22	0.0001

4.13 HEALTH AND SAFETY

4.13.1 Workplace Audits

Laboratory clinic and field audit reports filed between 1989-1991 were maintained by the SHO. During 1989, 14 lab reports were prepared; 18 in 1990, and 6 in 1991.

Between 1989-1991, 28 field audits were conducted. A table indicating the types of audits, and dates performed and are included in copies of the Interior and Exterior Safety Audit forms which were used for site safety evaluations Appendix O. In general these audits

TABLE 4-63 (cont'd). RESULTS OF STRUCTURAL EQUATIONS MODELING USING PHASE 5 LEAD LOADING DATA

Exogenous (Phase 3)	Estimate	t of F	p
Dependent: ln (PbH)			
Intercept	2.318	—	—
ln (PbD_{floor})	0.418	2.68	0.004*
ln (PbD_{window})	-0.365	-4.04	0.99*
ln (PbD_{mat})	0.196	2.83	0.003*
Age	0.019	5.09	0.0001
Sex	0.296	1.91	0.06
Areas* ln (PbD_{floor})		$F(2, 874) = 5.71$	0.003
A* ln (PbD_{floor})	-0.520		
B* ln (PbD_{floor})	-0.644		
Areas* ln (PbD_{window})		$F(2, 874) = 8.22$	0.0003
A* ln (PbD_{window})	0.485		
B* ln (PbD_{window})	0.571		
Areas		$F(2, 51) = 1.17$	0.32
A	-2.880		
B	-2.755		
Neighborhoods		$F(3, 51) = 0.81$	0.49
B	-1.148		
D	0.068		
G	-0.681		
Families		$F(51, 874) = 2.10$	0.0001

revealed that appropriate health and safety procedures were being followed. Common problems noted in some of the interior and exterior field audits included:

Interior Dust

- employees not wearing proper foot protection
- safe lifting practices not followed
- emergency phone numbers not available at site
- dust containers not equipped with covers.

TABLE 4-63 (cont'd). RESULTS OF STRUCTURAL EQUATIONS MODELING USING PHASE 5 LEAD LOADING DATA

Exogenous (Phase 3)	Estimate	t of F	p
Dependent: ln (PbD_{floor})			
Intercept	13.946	—	—
ln (PbD_{window})	-0.004	-0.04	0.52*
ln (PbD_{ext})	-1.669	-5.03	0.99*
ln (PbD_{entry})	0.142	2.33	0.01*
ln (XRF_{ext})	-0.490	-1.59	0.94*
House Age	0.097	3.01	0.002*
Areas* ln (PbD_{window})		F (2, 874) = 12.54	0.0001
A* ln (PbD_{window})	0.474		
B* ln (PbD_{window})	0.651		
Areas* ln (XRF_{ext})		F (2, 874) = 11.41	0.0001
A* ln (XRF_{ext})	-2.059		
B* ln (XRF_{ext})	1.251		
Areas* ln (PbD_{ext})		F (2, 874) = 7.23	0.0008
A* ln (PbD_{ext})	2.023		
B* ln (PbD_{ext})	1.363		
Areas		F (2, 53) = 1.45	0.24
A	-27.602		
B	-24.225		
Neighborhoods		F (3, 53) = 2.15	0.10
B	2.408		
D	2.370		
G	-2.817		
Apartments		F (53, 874) = 7.18	0.0001
Dependent: ln (PbD_{window})			
Intercept	10.768	—	—
Areas		F (2, 54) = 0.80	0.46
A	-2.195		
B	0.619		
Neighborhoods		F (3, 54) = 1.12	0.35
B	-4.524		
D	-1.855		
G	-0.253		
Apartments		F (54, 874) = 7.17	0.0001

TABLE 4-63 (cont'd). RESULTS OF STRUCTURAL EQUATIONS MODELING USING PHASE 5 LEAD LOADING DATA

Exogenous (Phase 3)	Estimate	t of F	p
Dependent: ln (PbD_{entry})			
Intercept	-17.098	—	—
ln (XRF_{int})	0.738	3.66	0.0002*
House Type	1.012	2.50	0.007*
House Age	0.170	4.01	0.0001*
Job	1.541	2.85	0.003*
Paint	0.995	2.34	0.01*
Areas		F (2, 54) = 2.77	0.07
A	-0.895		
B	4.724		
Neighborhoods		F (3, 54) = 0.25	0.86
B	-0.488		
D	-0.484		
G	1.500		
Apartments		F (54, 874) = 6.24	0.0001
Dependent: ln (PbD_{mat})			
Intercept	4.237	—	—
Job	2.719	5.47	0.0001*
Paint	1.065	2.91	0.002*
Areas		F (2, 53) = 1.62	0.21
A	2.243		
B	1.733		
Neighborhoods		F (3, 53) = 0.46	0.71
B	-0.548		
D	0.861		
G	0.154		
Apartments		F (53, 874) = 3.56	0.0001

Exterior Soil

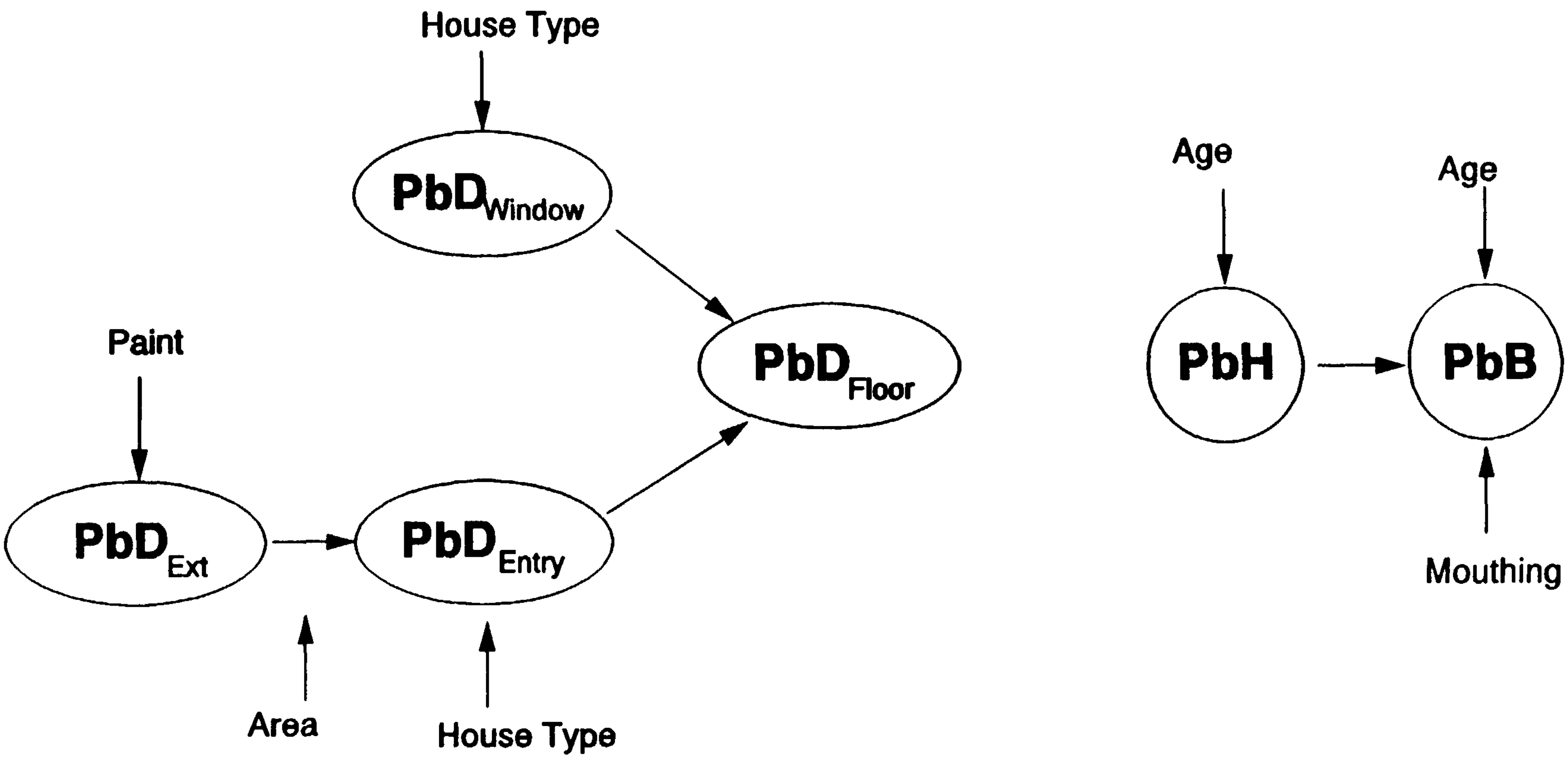
- employees not wearing proper foot protection
- dust control not maintained
- first aid kit and emergency phone numbers not available at site.

In addition to regular laboratory audits, walk-throughs to identify area lead exposure and to observe work practices in laboratories were conducted by a University of Cincinnati M.S. industrial hygiene student. These reports showed that exposures were far below all

TABLE 4-63 (cont'd). RESULTS OF STRUCTURAL EQUATIONS MODELING USING PHASE 5 LEAD LOADING DATA

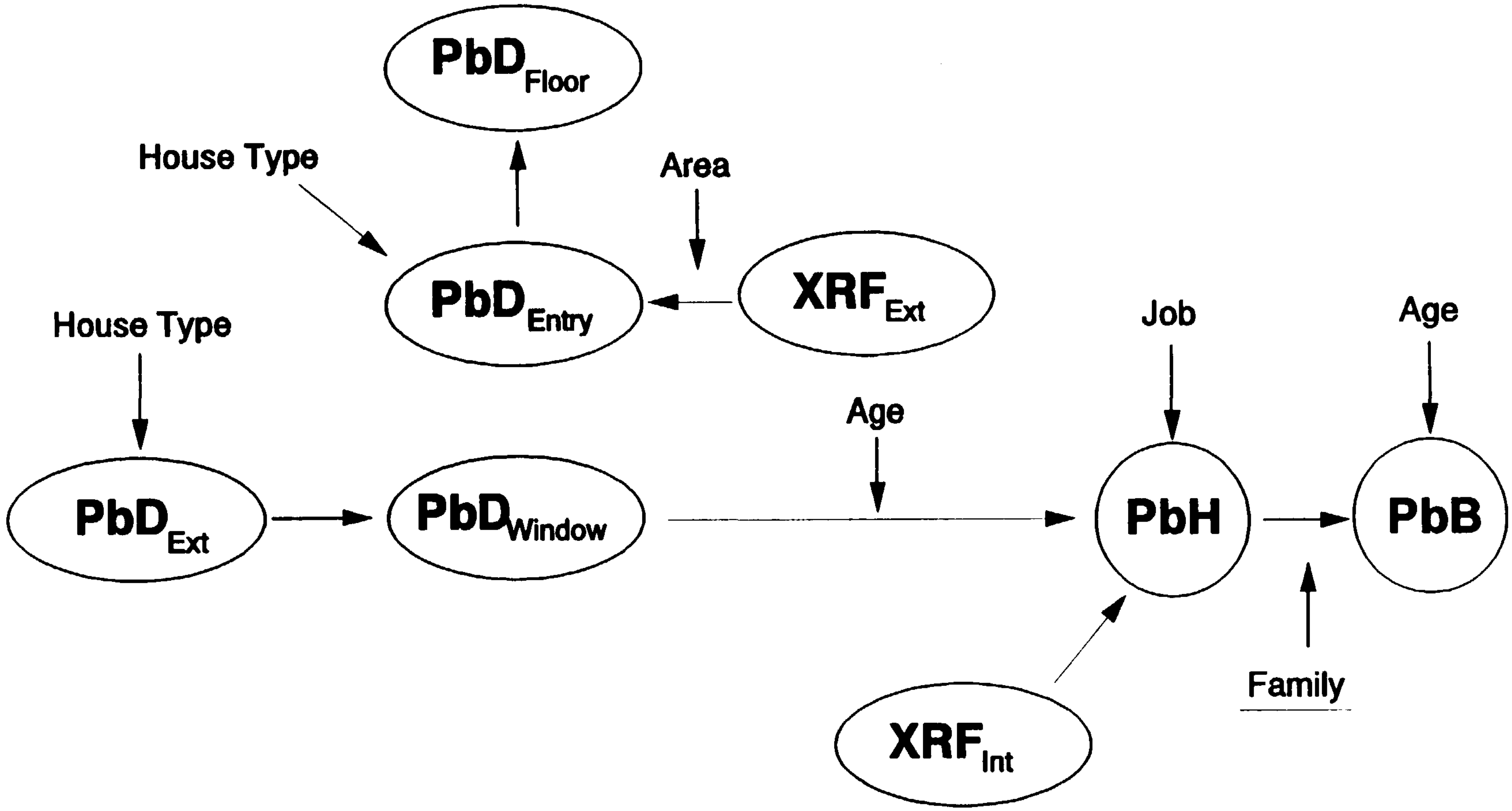
Exogenous (Phase 3)	Estimate	t of F	p
Dependent: ln (PbD_{ext})			
Intercept	12.691	—	—
ln (XRF_{ext})	0.211	3.07	0.001*
House Type	0.452	4.12	0.0001*
Areas		$F(2, 35) = 0.03$	0.97
A	0.226		
B	-0.170		
Neighborhoods		$F(3, 35) = 2.03$	0.13
B	-1.093		
D	0.830		
G	-2.099		
Dwellings		$F(35, 874) = 43.94$	0.0001
Dependent: ln (XRF_{int})			
Intercept	0.548	—	—
Areas		$F(2, 56) = 1.19$	0.31
A	0.621		
B	0.240		
Neighborhoods		$F(3, 56) = 0.34$	0.80
B	0.350		
D	0.022		
G	0.181		
Apartments		$F(56, 874) = 1.58$	0.005
Dependent: ln (XRF_{ext})			
Intercept	0.716	—	—
Areas		$F(2, 38) = 0.06$	0.94
A	0.125		
B	0.060		
Neighborhoods		$F(3, 38) = 0.08$	0.97
B	0.113		
D	0.063		
G	0.105		
Dwellings		$F(38, 960) = 1.79$	0.003

*One-tail p-value.



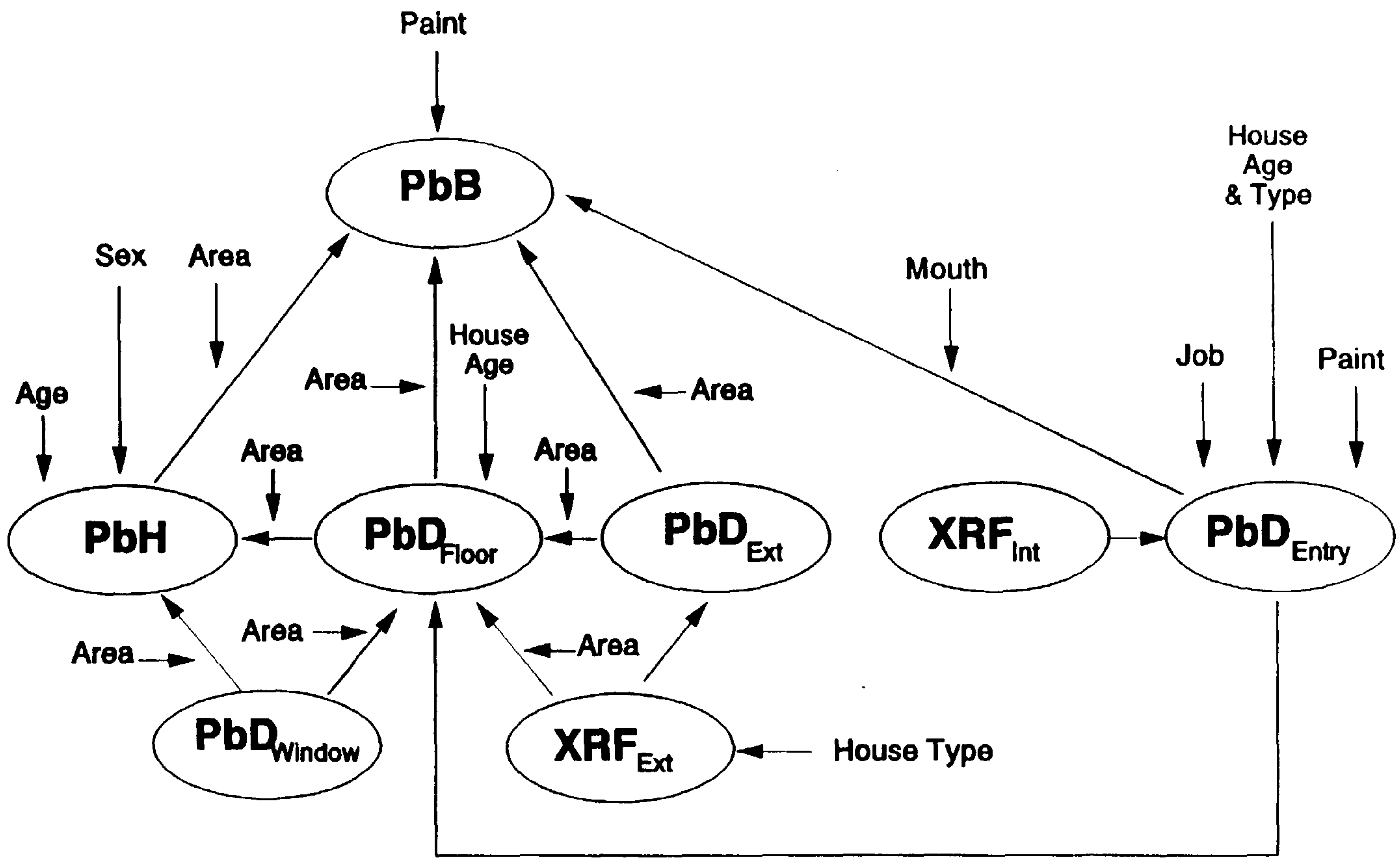
Note: Family, Apartment, and Dwelling effects are not shown

Figure 4-30. Phase 1 structural equation model for loading data.



Note: Family, Apartment, and Building effects are not shown

Figure 4-31. Phase 3 structural equation model for loading data.



Note: Family, Apartment, and Building effects are not shown

Figure 4-32. Phase 5 structural equation model for loading data.

currently accepted standards use by OSHA, or exposure guidelines from NIOSH and the ACGIH (see Appendix F).

4.13.2 Special Workplace Evaluations

4.13.2.1 Price Hill Facility

As with laboratory monitoring, personal and area air monitoring was performed by University of Cincinnati industrial hygiene graduate students during abatement periods. Early in the study a survey was conducted of a soil sieving operation at a temporary field site. Personal monitoring of three abatement employees' breathing zones was conducted for lead exposure as they performed their usual work tasks. The employees' breathing zones were monitored for time period up to 6.5 h. The ventilation results show that the hood sash should have been pulled down to the halfway position to achieve optimum protection. The samples collected indicated that the three workers were exposed to just detectable amounts of lead-containing dusts which were far below the OSHA General Industry action level for lead.

4.13.2.2 Noise Levels

A 1990 survey of the 12V portable exterior dust sampling vacuum equipment which revealed noise sound levels over 90 dB prompted the installation of a hearing conservation program which required employees to wear hearing protection when exposed to sound levels of 85 dB or greater.

During abatement in Fall 1991, personal sound levels measurements were obtained from three abatement workers: one backhoe operator, one bobcat operator and one randomly selected student. Each of these individuals wore personal noise dosimeters for 7 h. Results of the three samples (68-77dB) were well below the OSHA 85 dB action level for an 8 h day.

4.13.3 Manuscript on Safety and Health Plan

A manuscript on the development and implementation of this safety and health plan, previously introduced as Appendix H in Section 3.1, summarizes the above and additional material.

TABLE 4-64. PAINT LEAD XRF MEASUREMENTS IN REHABILITATED HOUSING FOR INITIAL RECRUITS, GEOMETRIC MEAN, (90 PERCENTILE) (mg/cm^2)

Location	Area A	Area B	Area C
Interior Trim (max)	1.1 (2.1) n=28	1.1 (2.6) n=50	1.3 (3.0) n=36
Interior Wall (max)	0.3 (1.2) n=29	0.5 (1.3) n=50	0.7 (1.7) n=36
Exterior Trim (max)	1.1 (1.8) n=29	1.0 (1.7) n=50	1.3 (3.5) n=36
Exterior Wall (max)	0.6 (2.1) n=26	0.3 (0.9) n=46	0.5 (1.5) n=29

TABLE 4-65. WATER LEAD CONCENTRATIONS IN REHABILITATED HOUSING FOR INITIAL RECRUITS, 30 MINUTE STAGNATION (μg/L)

	Area A	Area B	Area C
Geometric Mean	1.7	2.2	2.0
Maximum	3.4	13.6	10.6
90th %tile	1.9	6.1	3.4
Number of Samples	27	46	35

4.14 ABATEMENT COSTS

Abatement costs for soil, interior dust and exterior dust abatement for project years 1989, 1990 and 1991 are summarized in Table 4-66. The unit abatement costs are expressed per area, per housing unit (interior dust) and per study child. These units are somewhat arbitrary because there were many other children living in the study area, in addition to children enrolled in the study. For example, since the exterior abatement (soil and exterior

TABLE 4-66. ABATEMENT COSTS*

	1989	1990	1991	Overall
Soil Abatement				
Total Cost $	130,712	228,850**	65,537	425,099
Area. m^2	3,708	8,381	2,079	14,168
# Subjects	56	59	52	167
$/$M^2$	35.25	27.30	31.52	30.00
$/Subject	2,334	3,025	1,260	2,244
Interior Dust				
Total Cost $	112,746	23,632	46,082	182,460
# Housing Unit	93	16	41	150
Area, M^2	6,867	1,331	3,531	11,729
# Subjects	163	29	52	244
$/Housing Unit	1,212	1,477	1,124	1,216
$/$M^2$	16.42	17.75	13.05	15.56
$/Subject	692	814	886	748
Exterior Dust			***	
Total Cost$	37,366	66,977		104,343
Area, M^2	38,464	75,496		113,960
# Subjects	56	59		115
$/$M^2$	0.97	0.89		0.92
$/Subject	667	1,135		907

*Does not include preparation and inspection costs.
**About 22% of the cost was for abatement outside the actual study area.
***Exterior dust abatement performed only on a limited basis during 1991 and was not comparable to that performed in earlier years.

dust) was conducted on an area-wide basis, there were many children living in the area other than those who were enrolled in the study. In addition, there were many children in the abatement areas who were too old to be eligible for the study.

The total cost of the abatement, excluding methods development, preparation of contacts and inspection costs was about $712,000. The average total cost per study subject was $3899 with 58% of the cost for soil abatement, 19% for interior dust abatement and 23% for exterior dust abatement.

5. CONCLUSIONS

Conclusions will be presented in two formats: (a) as responses to questions asked concerning whether or not our evaluation of descriptive statistics of the study data provided evidence to support certain conclusions and (b) as general conclusion based on evaluation of study results. These are not mutually exclusive formats.

5.1 RESPONSE TO QUESTIONS

1. Do we find evidence that soil abatement reduced soil lead concentrations?

   Yes: Table 4-21, Area A, Phase 0 versus Phase 02
   Area B Phase 05 versus Phase 09

2. Do we find evidence that soil and exterior dust abatement alone reduced interior house dust Pb concentration?

   Not part of study design in Phases 00 through 05 but can compare Phase 06 vs. 07 in Area B when data are available.

3. Do we find evidence that interior dust abatement reduced interior dust Pb concentration?

   No: Table 4-33; Area A and B; Floors; Phases 01 vs. 02.

4. Do we find evidence that interior dust abatement, alone, reduced interior dust Pb loading?

   Yes: Table 4-33; Area B; Floors; Phase 01 vs. 02.

5. Do we find evidence that soil and exterior dust abatement reduced exterior dust lead concentration?

   No: Table 4-28, Area A, Phase 01 vs. Phase 02
   Area B, Phase 05 vs. Phase 09

   loading?

   No: Table 4-30, Area A, Phase 01 vs. Phase 02
   (except targeted samples)

6. Do we find evidence of soil recontamination?

   No: Table 4-21; Area A; Phase 02 vs. 09.

7. Do we find evidence of exterior dust recontamination?

   Can't test since initial reduction not demonstrated (<u>except target samples</u>).

8. Do we find evidence of interior dust recontamination?

   Yes: Table 4-33; Area B; Floors; Phase 02 vs. 05.

9. Do we find evidence of the impact of abatements on hand lead?

   No: Table 4-46; Area A or B; Phase 01 vs. 05 or 09.

10. Do we find evidence of the impact of abatements on blood lead?

    Perhaps: Table 4-41; Area B; Phase 01 vs. 05
    Table 4-44; Area B; Phase 01 vs. 05
    Table 4-45; Area B; Phase 01 vs. 05.

11. Do we find evidence that intercorrelations among measures were as hypothesized prior to any abatements?

    Yes: PbD (exterior) vs. PbD (interior)
    PbD (interior) vs. PbH
    PbH vs. PbB

12. Since the findings are largely negative, do we have evidence that they are <u>not</u> due to sampling or analytical error?

    Yes: extensive QC data confirms accuracy and precision of measurements.

13. Do we have any evidence that abatements might have caused a transient increase in exposure?

    No.

14. Was there evidence that the environment was stable over the course of the study?

    No: In the control area environmental lead levels varied widely during the course of the study.

5.2 GENERAL CONCLUSIONS

(1) As a result of abatement geometric mean soil lead concentrations decreased in the top 2 cm samples by 146 ppm in Area A and by 102 ppm in Area B.

(2) As anticipated, soil lead concentrations were higher when a building was located near the sample location (line (source) sampling pattern) than for areas more remote from such structures (line (area) sampling pattern).

(3) Soil concentrations were also greater as anticipated for soil areas were building debris was observed in the bottom 2 cm of the 15 cm soil cores.

(4) Exterior dust abatement was not effective in reducing lead loadings, as measured in samples collected within weeks of abatement, except at locations near the entry to subjects' houses where more than a 50% reduction was observed in the first post-abatement sample.

(5) Interior dust abatement was effective in reducing interior dust lead loadings by about 40% in Area A and by about 60% in Area B. Loadings in Area B, where only interior abatement has occurred, showed evidence of some recontamination 3 mo later. There was some indication that the impact of the abatement persisted 10 mo later in Area A and perhaps as long as 22 mo post-abatement.

(6) There was no evidence that blood lead levels were reduced by soil lead or dust abatement in Area A. There was a slight reduction (net reduction over control area) of 0.6 μg/dL in Area B that may be attributed to interior dust abatement (this difference was not statistically significantly).

(7) The inability to achieve a sustained reduction in exterior dust lead loadings was probably an important contributing factor for the lack of blood lead level reduction.

(8) The interior dust abatement in this project was performed under rather favorable conditions: (1) it was performed in completely rehabilitated housing with a lack of significant amounts of lead-based paint and with tight floors with no dust-laden cracks); and (2) the protocol for abatement featured a substantial amount of furniture and carpet replacement as well as wet and dry cleaning. Even under these somewhat ideal conditions, reduction in interior entry dust lead loadings of only about 50% were reached. Interior floor dust lead loadings were 37% lower 10 mo post-abatement in Area A. In other types of housing containing lead-based paint, with housing in poorer condition and with a less rigorous protocol applied, a single time interior dust abatement would not be as likely to achieve even these modest results.

6. REFERENCES

Bornschein, R.L.; Hammond, P.B.; Dietrich, K.N. (1985) The Cincinnati Prospective Study of low level lead exposure and its effects on child development: protocol and status report. Environ. Res. 34:4-18.

Bornschein, R.L.; Krafft, K.M.; Clark, C.S.; Peace, B.; Hammond, P.B. (1986) External surface dust lead, interior house dust lead and childhood lead exposure in an urban environment. In D.D. Hemphill (ed), Trace Substances in Environmental Health II. University of Missouri, Columbia,

Clark, S.; Bornschein, R.L.; Succop, P.; Que Hee, S.S.; Hammond, P.B.; Peace, B. (1985) Condition and type of housing as an indicator of potential environmental lead exposure and pediatric blood lead levels. Environ. Res. 38:46-53.

Clark, S.; Bornschein, R.L.; Succop, P.; Peace, B.; Ryan, J.; Kochanowski, K. (1988) The Cincinnati Soil Lead Abatement Demonstration Project. In B.E. Davies and B.G.Wixson (eds), Lead in Soil: Issues and Guidelines. Science Reviews Limited, Northwood, Great Britain.

Clark, S.; Bornschein, R.; Succop, P.; Roda, S. (1991) Urban lead exposures of children in Cincinnati, Ohio. Chemical Speciation and Bioavailability 3:163-171.

Chisolm, J.J. Jr.; Brown, D.H. (1975) Micro-scale photofluorometric determination of "free erythrocyte porphyrin (protoporphyrin IX). Clin Chem 21:1669-1682.

LIST OF APPENDICES

APPENDIX A

Calculation of Required Sample Size

This appendix was Addendum A "Power Calculations" of the September 30, 1988 Grant Agreement between the U.S. Environmental Protection Agency and the University of Cincinnati.

Reference (5) in this document is:

Succop, P.A., O'Flaherty, E.J.,Bornschein, R.L., Clark, C.S., Kraftt, K., Hammond, P.B., Shukla,R. A kinetic model for estimating changes in the concentration of lead in the blood of young children. In: Lindberg, S.E. and Hutchinson, T.C. (Eds). Proceedings of the International Conference: Heavy Metals in the Environment, Vol.2 New Orleans, September 21987, pp. 289-291.

DEMONSTRATION OF POWER AND SAMPLE SIZE CALCULATIONS

Estimates of the effect sizes to be expected are obtained from Kinetic Model (5). Assume that we are sampling children whose ages are distributed uniformly across the age range of interest (12 to 60 months), half of whom have blood leads (PbB's) whose kinetic change with time will resemble that of children having resided continuously in Rehabilitated housing, the remaining half having PbB's whose kinetic change with time will resemble that of children having resided continuously in Satisfactory housing to their current age, t.

From Kinetic Model (5), a child residing continuously in a single housing category from birth is modeled

$$PbB_t = .94*PbB_{prenatal}*(1-exp(-.063*t_{prenatal}))*(exp(-.063*t)) + a_1*(1-exp(-.063*t)), \qquad (1)$$

where a_1 is the estimated asymptote for the housing category in which the child resides. For a child continuing to reside in this category for Δt additional months, PbB is modeled

$$PbB_{t+\Delta t} = .94*PbB_{prenatal}*(1-exp(-.063*t_{prenatal}))*(exp(-.063*[t+\Delta t])) + a_1*(1-exp(-.063*[t+\Delta t])), \qquad (2)$$

at time $t+\Delta t$, while a child moving to a different category of housing has an expected PbB of

$$PbB_{t+\Delta t} = .94*PbB_{prenatal}*(1-exp(-.063*t_{prenatal}))*(exp(-.063*[t+\Delta t])) + a_1*(1-exp(-.063*t))*(exp(-.063*[\Delta t])) + a_2*(1-exp(-.063*[\Delta t])) \qquad (3)$$

where a_2 is the asymptote for the category into which the child moves. The prenatal effect in Eqs. (1) through (3) may be modeled assuming full-term pregnancies ($t_{prenatal}=9$) and by using the observed Lead Program Project's prenatal, maternal PbB mean of 8.2.

The expected mean PbB for children at the 3 sampling occasions planned by the study design may be estimated by integrating the variable t in Eqs. (1) through (3) above in the limits [12,60] and dividing by 48, i.e., the range in ages of children to be sampled. Integrating (1) provides an estimate of the geometric mean PbB for all children to be sampled just prior to abatement:

$$(48)^{-1}\int_{12}^{60} PbB_t dt = .495808123 + .850574234 a_1. \qquad (4)$$

The design of the abatement study calls for repeated sampling of PbB's 6 and 12 months after abatement. Integrating (2) for $\Delta t=6$ and $\Delta t=12$ provides

$$(48)^{-1}\int_{12}^{60} PbB_{t+6} dt = .340661394 + .897332078 a_1, \qquad (5)$$

and

$$(48)^{-1}\int_{12}^{60} PbB_{t+12} dt = .234062694 + .929458604 a_1, \qquad (6)$$

respectively. Assume that <u>soil</u> abatement has an equivalent effect to that of a move for a child from a Rehabilitated or Satisfactory house to a newer (Post World War 2) residence. Then integrating Eq. (3) for $\Delta t=6$ and $\Delta t=12$ provides,

$$(48)^{-1}\int_{12}^{60} PbB_{t+6} dt = .340661394 + .584415201 a_1 + .312916877 a_2, \qquad (7)$$

and

$$(48)^{-1}\int_{12}^{60} PbB_{t+12} dt = .234062694 + .401522254 a_1 + .527916782 a_2, \qquad (8)$$

as expected geometric mean PbB's for children living in abated residences 6 and 12 months, respectively, following abatement.

Using the average of the two asymptotes estimated for the Rehabilitated and Satisfactory categories as representative of pre-abatement asymptotes provides $a_1=\frac{1}{2}(17.19+19.97)= 18.58$. The asymptote for the Private Post World War II housing category provides $a_2=14.26$. Then the geometric mean PbB's for the 5 areas to be used in this study at the 3 sampling occasions may be estimated from Eqs. (4) through (8) and are listed in the following Table.

				AREAS D & E Interior dust	
	AREA A	AREA B	AREA C	nonabated	abated
April-May, 1989	16.299	16.299	16.299	16.299	16.299
October, 1989	15.661	15.661	17.013	17.013	17.013
April-May, 1990	15.222	15.222	17.503	17.503	17.503

These estimates assume that removal of interior dust will provide no additional diminishment in PbB.

Assuming an equal number of children will be sampled in each group, the grand ln(PbB) means are estimated to be 2.7911, 2.8009, and 2.8065 at these 3 sampling occasions. The effect sizes, τ, expected to occur in separate analyses of covariance of $\ln(PbB_{t+6})$ and $\ln(PbB_{t+12})$ for each of the j areas are

$$\tau_{j(t+6)} = \bar{Y}_{j(t+6)} - \bar{Y}_{(t+6)} - \beta(\bar{X}_{j(t)} - \bar{X}_{(t)}), \text{ and} \tag{9}$$

$$\tau_{j(t+12)} = \bar{Y}_{j(t+12)} - \bar{Y}_{(t+12)} - \beta(\bar{X}_{j(t)} - \bar{X}_{(t)}) \tag{10}$$

where $\bar{Y}_{(t+\Delta t)}$ is the mean of $\ln(PbB_{t+\Delta t})$, and $\bar{X}_{(t)}$ is the mean of $\ln(PbB_{36})$. From the above table, we have for these τ_j's:

	Soil abated areas (A,B)	Non-soil abated areas (C,D,E)
October, 1989	-.0497	.0331
April-May, 1990	-.0838	.0559

The sum of squares for testing the hypothesis of no effect on $\ln(PbB_{t+\Delta})$ due to soil abatement is

$$n\Sigma\tau_{j(t+\Delta)}^2 \tag{11}$$

where n is the number of children to be sampled in each area. Using the $\tau_{j(t+\Delta)}$'s from the above table, we have

$$n\Sigma\tau_{j(t+6)}^2 = .0082n; \; n\Sigma\tau_{j(t+12)}^2 = .0234n. \tag{12}$$

Assume that after statistical correction for age and the initial PbB collected in Spring, 1989, the children sampled in the soil abatement study have residual PbB's 6 and 12 months following abatement that are akin to those observed in the Lead Program Project's cohort at 42 and 48 months. (Once again we use the assumption of sampling children whose average age at the beginning of the study is 36 months.) The MS_E from analyses of covariance of the Lead Program Project's data may then be used to estimate the expected residual variance to be encountered in this study. Specifically, we estimate that

$$MS_E[\ln(PbB_{42}) \cdot [\ln(PbB_{36}), \text{Housing categories}]] = .07628 \tag{13}$$

and

$$MS_E[\ln(PbB_{48}) \cdot [\ln(PbB_{36}), \text{Housing categories}]] = .05756. \tag{14}$$

Housing category has also been removed from the residual variation since the abatement study plans to follow only non-movers, which we assume are, once the study begins, in a non-changing environmental "category". The effect of housing over and above the prior PbB is quite minor at these ages.

Thus, the noncentrality parameters that occur in testing the overall hypothesis of no soil abatement effect are

$$\lambda_{(t+6)} = \frac{.0082n}{.07628} = .1079n, \tag{15}$$

$$\lambda_{(t+12)} = \frac{.0234n}{.05756} = .4064n. \tag{16}$$

using all 5 groups in ANACOVA.

The power for detecting a significant effect due to abatement on PbB at t+6 and t+12 months is then estimated to be:

n	power(t+6)	power(t+12)
10	.103	.293
15	.136	.444
20	.173	.585
25	.214	.704
30	.253	.794
35	.294	.861
40	.336	.909
45	.375	.941
50	.415	.963

80% power for finding a significant effect of soil abatement on $\ln(PbB_{t+12})$ is expected to result if at least 31 children in each of the 5 areas are sampled. Other effects of abatement, especially those which are captured in the environmental measurements, will have at least, and probably much greater, power than that shown here for PbB, since our published longitudinal study data has indicated much stronger relationships among the environmental measures of housing, soil lead, and dust lead, than those found between the environment and indices of body burden such as PbB.

APPENDIX B

Letter to Prospective Families and Project Fact Sheet

University of Cincinnati

Cincinnati Soil Project

1142 Main Street
Cincinnati, Ohio 45210-1936
Phone (513) 651-4774

May 26, 1989

Dear Resident:

Do you remember our census of young children that you participated in?

Well, you may be interested in knowing that partially as a result of that census, your housing is in one of the areas that are eligible to participate in a project that the University of Cincinnati, with cooperation from the Cincinnati Health Department, is conducting.

The project is designed to determine if certain environmental improvements are able to reduce the exposure of young children to lead from soil and dust. You and some other residents in your neighborhood will be asked to bring your young children (under five years of age) to the Soil Project Office to enroll in the study and to have their blood measured for lead over the next two years.

Enclosed is a fact sheet that provides some further information.

In the meantime, if you have any questions, please call JoAnn Grote or Sherry Wilkens (651-4774).

Sincerely,

JoAnn Grote

JoAnn Grote
Resident Coordinator

Sherry Wilkens

Sherry Wilkens
Recruiter

Cincinnati Soil Project

What is the Soil Project?

It is a three year research project funded by the U.S. Environmental Protection Agency to the University of Cincinnati Department of Environmental Health with a subcontract to the Cincinnati Health Department.

What is its purpose?

Its purpose is to determine if efforts to reduce the amount of lead in available soil and dust in residential areas can lower the blood lead of young children (under 5 years of age) living in these areas.

How will available soil lead be reduced?

Two methods will be used: removal of soil to a six inch depth and replacing it with fresh topsoil or cultivation of the soil if only the top layer is higher in lead. New sod will be placed on areas where soil has been either removed or cultivated.

How will dust lead be reduced?

In exterior paved areas (for example, streets, alleys and sidewalks) vacuum equipment will be used to remove dust and dirt. Dust from inside of homes will be removed by use of special vacuum equipment and in some cases by a limited replacement of carpets and furniture.

How were areas selected?

Areas selected had to have a large number of children less than five years of age and a high percentage of FHA rehab housing.

What is involved in the project?

In addition to the soil and dust activities mentioned above, blood lead of children will be periodically determined (a total of 5 times over three years) and extensive environmental sampling (for example, soil and dust from both inside and outside homes) will take place a total of 7 times in three years.

Will soil and dust clean-up occur the same time in all areas?

No, because this is a research project, clean-up activities will be spread over a three year period.

Will public recreation areas be included?

Yes they will if they lie within areas being studied. We will work closely with the Recreation Commission to make sure that disruption of their use is kept to a minimum and that appropriate surface coverings are placed around swings etc.

Why was Cincinnati chosen?

It was chosen for several reasons (1) the existence of an established lead research group at the University of Cincinnati, (2) evidence of high soil and dust lead in residential areas, (3) an active lead screening program in the Cincinnati Health Department, and (4) a history of cooperation between the city, the University and the medical community.

(OVER)

APPENDIX C

Letters to Community Leaders and Property Owners Describing Study and an Accompanying Project Fact Sheet

University of Cincinnati

Cincinnati Soil Project

1142 Main Street
Cincinnati, Ohio 45210-1936
Phone (513) 651-4774

We would like to inform you about a University of Cincinnati research project involving small portions of several Cincinnati neighborhoods. The Cincinnati Health Department is also involved with us in this effort.

The project goal is to determine if reducing the amount of lead in soil and dust will reduce the exposure of young children to lead. The focus is on those areas where there is a high concentration of rehabilitated housing where the sources of lead are generally thought to be from the routine entry of dust into the home from outside paved and soil areas.

The environmental improvements will include soil surface clean-up in areas with lead levels above a pre-determined value, extensive cleaning of paved areas, and dust removal inside of homes of young children who are enrolled in the project. As a part of the dust removal from the interiors of homes, a limited amount of furniture and carpets may be replaced. Exterior clean-up activities will be available for all properties within defined areas while interior clean-up will occur only in homes where young children are enrolled in the project.

Because this is a research project not all clean-up activities are scheduled to occur during the same year. The established schedule is as follows:

Neighborhood Area	Year	Clean-up
Portions of Pendleton	1989	Interior and Exterior
Portions of Findlay Market and Back St. area	1989	Interior
Portions of Findlay Market and Back St. area	1990	Exterior
Portions of Glencoe Place and Mohawk area	1991	Interior and Exterior

The specific boundaries of these areas are shown on the enclosed sheets.

An initial soil sampling and a census of young children have already occurred as part of our efforts to determine eligible areas. Actual recruitment of participating families with young children is scheduled to start in the near future.

Enclosed is an information sheet which provides some further information on this project. Should you have any questions, please call Linda Conway-Mundew at the Soil Project Office (651-4774).

Sincerely,

Linda Conway-Mundew
Linda Conway-Mundew
Project Administrator

Scott Clark
Scott Clark
Principal Project Investigator

JoAnn Grote
JoAnn Grote
Resident Coordinator

Bill Menrath
Bill Menrath
Property Coordinator

LCM:SC:JG:BM/jo

Enclosures

University of Cincinnati

Cincinnati Soil Project

1142 Main Street
Cincinnati, Ohio 45210-1936
Phone (513) 651-4774

BACKGROUND INFORMATION ON CINCINNATI SOIL PROJECT

1. This is a demonstration project requested by the U.S. Environmental Protection Agency to provide answers to <u>specific</u> questions regarding lead in the environment.

2. The specific questions to be answered are:

   (a) Are any of the following methods effective in reducing exposure of young children (less than 5 years of age) to lead? reduction of lead in soil available to the children, reduction of lead in exterior dust, and reduction of lead in interior dust.

   (b) Which of the above methods, alone or in combination with one or both of the other methods, is most cost effective in reducing the exposure to lead?

   (c) How quickly do soil and dust areas become recontaminated after clean-up?

3. In order to answer the above questions in an efficient way it is <u>essential</u> to select areas with a high density of young children and in which a high percentage of the children live in housing where lead in soil and dust are the major immediate sources of lead to the children.

4. In Cincinnati houses rehabilitated under various HUD programs, where lead paint availability on the interior and exterior of homes was virtually eliminated, represent the type of housing where the lead in soil and dust are thought to represent the major sources available to the children.

5. The purpose of this demonstration project,therefore, is <u>not</u>:

   (a) To reduce the blood lead levels of the children with the <u>highest</u> blood lead (such children almost always reside in houses that have not had their paint lead removed); or

   (b) To remove the <u>most</u> lead-contaminated soil in the city (again, such soil is likely to be adjacent to structures still having lead-based paint on them).

6. The purposes of the demonstration project require that we select portions of neighborhoods that will enable us to provide answers to the US EPA's questions, within the constraint of time and money imposed by the project, and within the research guidelines developed by the US EPA, the Centers for Disease Control and by our research group.

(OVER)

7. There are many factors that constrain what we do and how we do it. Among these factors are the following:

(a) Season of the year influences the degree of lead exposure and was considered in deciding when we will abate lead and when we will measure blood level.

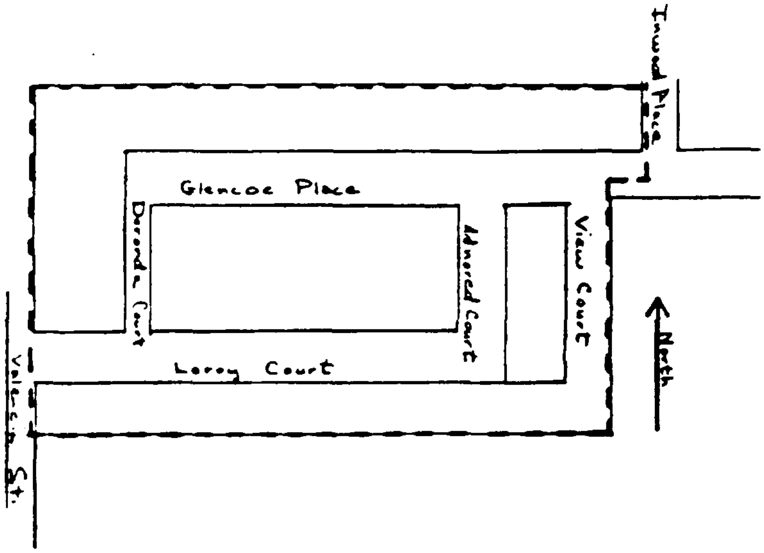
(b) There must be appropriate comparison neighborhood areas that are not soil or dust abated the same year; these comparison areas must be very similar to the areas being abated.

(c) In order for our findings to be statistically significant, the areas selected must have a minimum average of 50 children that complete the two-year study. Based on our past experience we know that only 80 % of those families we contact will participate and that, for various reasons, only 80 % of those who join will actually complete the study.

Therefore each study and comparison area must have an average of about 75 children less than 60 months of age at the beginning of recruitment.

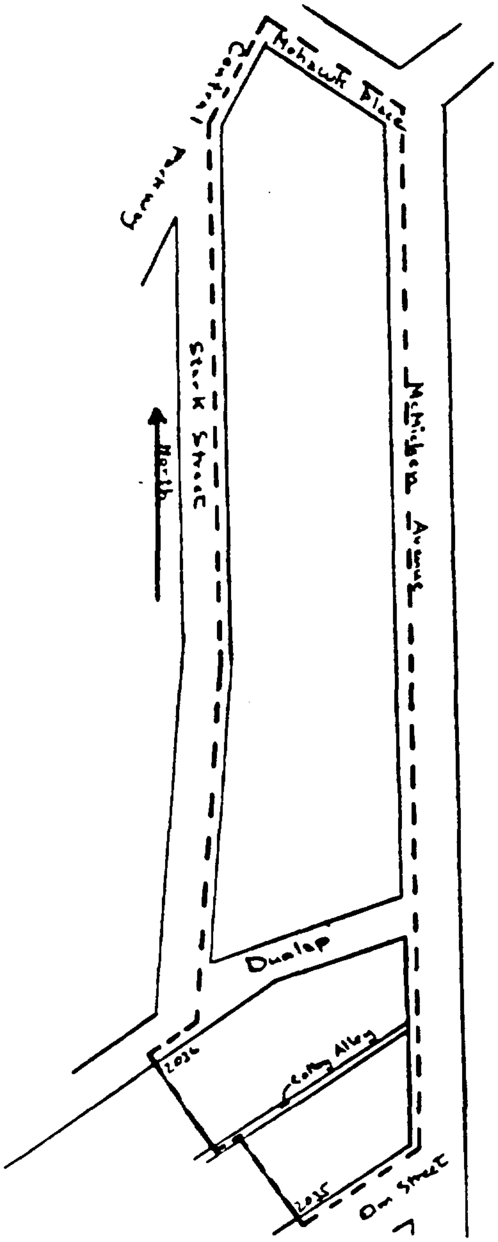
8. The areas that meet the criteria for inclusion in the project are portions of the following neighborhoods: Pendleton, Findlay-Back, and Glencoe-Mohawk. Other areas considered include North and South portions of Lower Price Hill, the John St. area of the West End,and portions of Walnut Hills.

9. Through an agreement with the City of Cincinnati that was required prior to sampling city-owned property, we agreed to abate any city property found to contain soil with lead concentrations requiring some abatement according to our guidelines, regardless of whether that area was eventually selected for inclusion in the study.



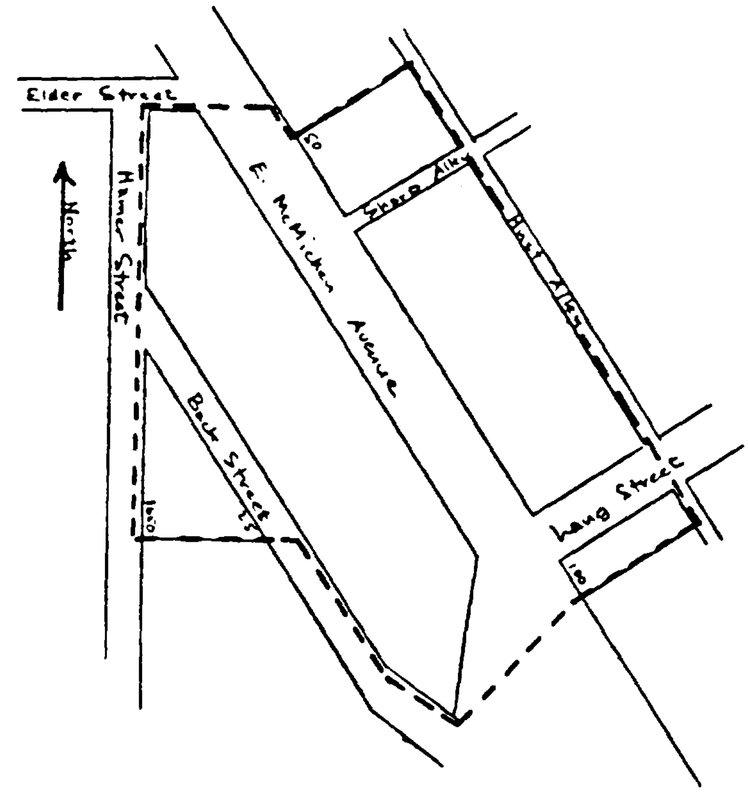
GLENCOE NEIGHBORHOOD

The properties included in the Glencoe neighborhood will be those properties fronting on the north and south sides of Glencoe Place west of Inwood Place and View Court, properties fronting on Leroy Court, properties on Adnored, and properties on Deronda.



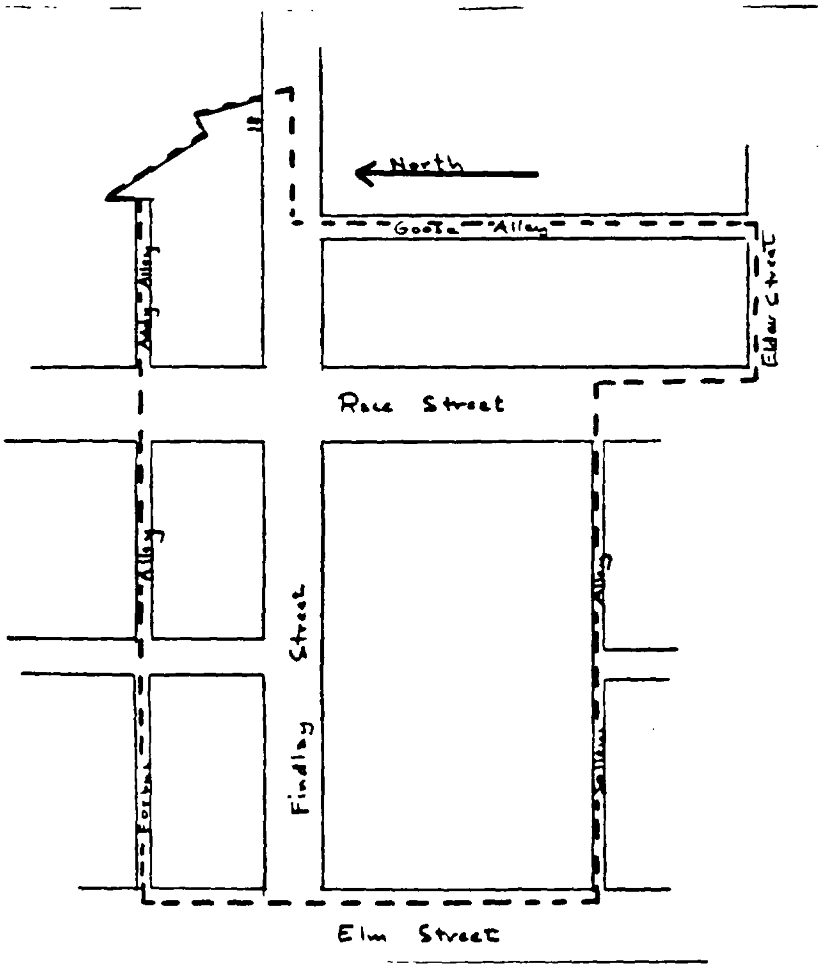
MOHAWK NEIGHBORHOOD

The Mohawk neighborhood boundary begins at the intersection of Central Parkway and Mohawk Place and proceeds east on Mohawk Place to McMicken Avenue, southeast on McMicken Avenue to Elm Street, south on Elm Street to the parcel of property at 2035 Elm Street along the boundary of that parcel to Colby Alley, across Colby Alley to the parcel of property at 2036 Dunlap, north on Dunlap to Stark Street, northeast along Stark Street to Central Parkway, north on Central Parkway to the intersection of Central Parkway and Mohawk Place. The Mohawk neighborhood is enclosed within these boundaries.



THE BACK STREET NEIGHBORHOOD

The Back Street neighborhood boundary begins at the parcel of property located at 1650 Hamer Street and proceeds north on Hamer Street to the intersection of Hamer and Elder, east on Elder Street to the intersection of Elder and East McMicken, southeast on East McMicken to the parcel of property at 50 East McMicken, along the boundary of that parcel to Hust Alley, southeast along Hust Alley, across Lang Street to the parcel of property at 100 East McMicken Avenue, along the boundary of that parcel to East McMicken Avenue and across East McMicken Avenue to Back Street, northwest on Back Street to the parcel of property located at 25 Back Street, along the boundary of that parcel to the starting point at 1650 Hamer Street. The Back neighborhood is enclosed within these boundaries.

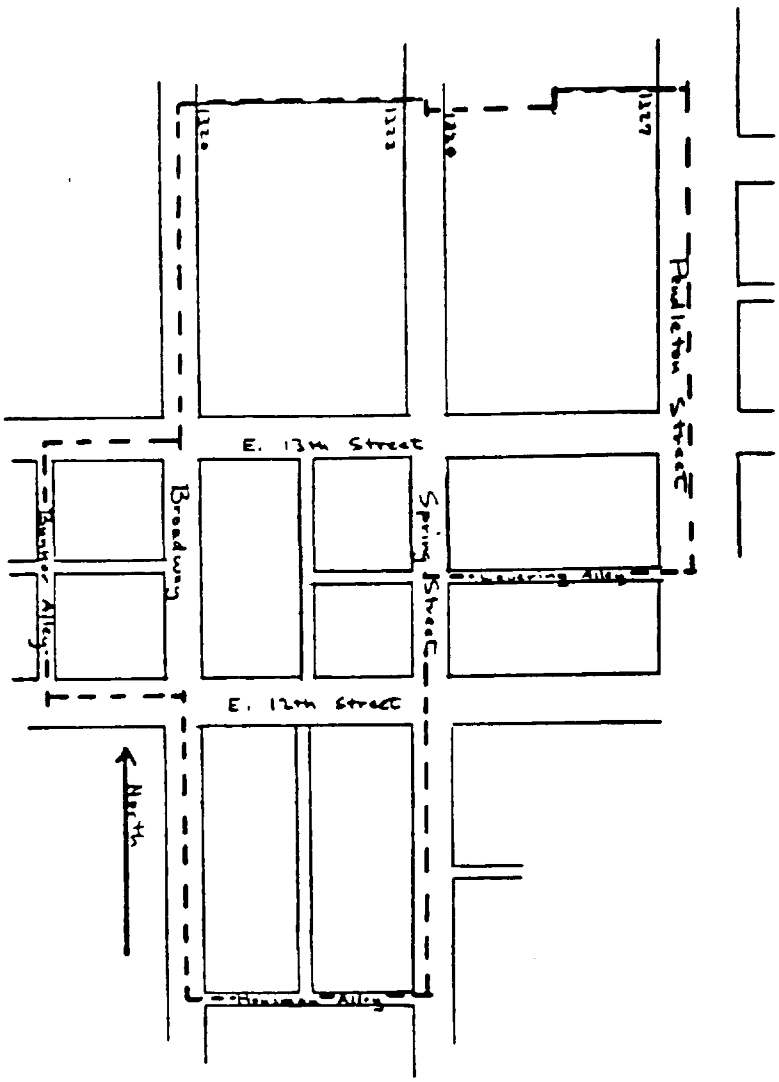


FINDLAY NEIGHBORHOOD

The Findlay neighborhood boundary begins at the intersection of Elm Street and Sellew Alley and continues north along Elm Street to Forbus Alley, west on Forbus Alley to Race Street, across Race Street to Addy Alley, east on Addy Alley to the parcel of land at 18 Findlay Street, west on Findlay to Goose Alley, south on Goose Alley to Elder Street, west on Elder Street to Race Street, north on Race Street to Sellew Alley, west on Sellew Alley to Elm Street, returning to the starting point at the intersection of Sellew Alley and Elm Street. The Findlay neighborhood is enclosed within these boundaries.

PENDLETON NEIGHBORHOOD

The Pendleton neighborhood boundary begins at the intersection of Housman Alley and Broadway and proceeds north on Broadway to East 12th Street, west on East 12th Street to Bunker Alley, north on Bunker Alley to East 13th Street, east on East 13th Street to Broadway, north on Broadway to 1320 Broadway, continuing east on that parcel of property to Spring Street, including 1323 and 1320 Spring Street, continuing east along the parcel at 1320 Spring Street, continuing east along the parcel at 1327 Pendleton Street to Pendleton Street, south on Pendleton street to Levering Alley, west on Levering Alley to Spring Street, south on Spring Street to Housman Alley, west on Housman Alley to the starting point at the intersection of Housman Alley and Broadway. The Pendleton neighborhood is enclosed within these boundaries.



APPENDIX D

Sample Project Newsletters

When people are smoking around you, you smoke too and it's harmful. The smoke that rises off the end of a burning cigarette, called sidestream smoke, is twice as high in tar and nicotine as that which the actual smoker inhales. The smoke is filled with hundreds of chemicals many of which are known to cause cancer. Studies show that secondhand smoke can cause non-smokers to develop heart disease and lung cancer.

If you smoke, you probably don't realize how your smoking can cause harm to those you love. When non-smokers like young children are forced to breathe air that is filled with cigarette smoke, things happen that you can't see. Their heart beat speeds up, their blood pressure rises. And dangerous carbon monoxide seep into their blood. Babies of parents who smoke at home have a much higher rate of lung diseases such as bronchitis and pneumonia than babies of nonsmoking parents. Cigarette smoke can actually aggravate and even trigger symptoms in some asthmatic children. Parents should only smoke outside the home or, better yet, quit smoking completely. More than you may realize, you set an example for your children. Most teenagers who smoke on a regular basis are from families where one or both parents smoke.

Here's how to quite smoking today!

- Decide that quitting smoking is one of the best things that you could do for yourself and your family.
- When you want to quit, you will quit. Keep working at it!
- Make a list of reasons why you want to quit and post it somewhere readily noticeable.
- Try whatever seems best to you. Taper off. Or quit all at once.
- Switch to a brand you dislike.
- Throw away your matches. If getting your cigarette lit is difficult, maybe you won't smoke.
- Remind yourself every morning how important it is to quit. Millions of people have stopped smoking. Are their families more important than your family?

Contact the American Lung Association of S.W. OH at 751-3650 about program that can help you quit.

•••

SUMMERTIME FOOD SAFETY RULES:

With warm weather comes picnics, barbecues and food poisoning. If you could just throw the refrigerator under one arm and take it with you, there wouldn't be any problem in caring for food to go.

That's because the best way to fight food poisoning is to keep perishable foods-especially meat and poultry-cold between preparation and serving.

- Keep food cold. This is the best way to fight bacteria.
- Keep bacteria on your hands out of food-Everyone in the family should wash hands before preparing food.

- Don't spread bacteria from raw meat and poultry to other food. Wash hands after contact with raw meat and poultry. Use a fresh plate-and utensil set for each food.
- Thoroughly cook raw meat, poultry and fish.
- Don't use food from damaged containers-Check cans and glass jars for dents, cracks or bulging lids; paper packages for leaks and stains.
- Make a summer check of your appliances-Check that your refrigerator registers a safe 40° F or lower. Freezers should be set at 0° F or lower.

•••

2 envelopes of unflavored gelatin
2 1/2 cups water
1 package (6 ounces) or
2 packages (3 ounces) flavored Jell-o

The kids will love it! Dissolve unflavored gelatin in one (1) cup of cold water. Set aside. In saucepan bring 1 cup of water to a boil and add Jell-o. Add dissolved unflavored mixture. Stir and add 1/2 cup cold water. Pour into a lightly greased pan and refrigerate until firm (about 2 hours). Cut into squares or use cookies cutters and store in an airtight container in the refrigerate.

HOMEMADE POPSICLES

Pour juice or Kool-aid (add slices of fruit if desired) into small containers or paper cups. Place in freezer. When slightly frozen, add a popsicle stick or straw. Place back in freezer until frozen. Loosen popsicle by running a little warm water over container.

BANANA PUDDING

6 to 8 medium size bananas
1 large package of instant vanilla pudding
8 oz container of cool whip (any store brand will due)
6 oz container of sour cream (if you like it, not necessary)
1 box of vanilla wafers

In a large bowl mix instant pudding using directions for making pie on package. Add container of cool whip and sour cream (if desired) to pudding mixture. Begin by starting with a layer of pudding in bottom of a bowl, add a layer of vanilla wafers, next slice bananas on top of wafers. Continue layering, ending with a layer of crushed vanilla wafer. Enjoy!

•••

BIRTH ANNOUNCEMENTS

The Cincinnati Soil Project proudly announces the birth of the following babies :

Mathias G.	1/22/91
Dorian C.	1/29/91
Christopher D.	2/17/91
Gwendolyn D.	3/14/91
David W.	4/20/91

Good Luck in the future!!!!!!

•••

SUMMERTIME WORD SEARCH

S	C	Z	I	C	S	C	B	B	A	M	L	R
U	K	A	N	E	T	C	D	O	S	L	I	A
N	J	S	P	T	Y	A	I	N	P	B	N	L
N	L	U	M	S	N	L	P	S	I	Q	G	L
T	K	P	V	O	T	G	D	B	C	E	N	A
A	P	Q	M	S	B	U	I	G	N	L	P	B
J	R	R	W	P	S	T	E	J	I	D	T	S
E	L	T	M	I	A	B	S	L	C	E	S	E
S	S	N	P	O	P	S	I	C	L	E	E	A
B	O	S	S	E	V	E	M	I	U	B	D	B
D	T	W	F	M	S	G	O	P	T	O	N	W
F	X	I	N	M	E	X	N	P	W	S	G	O
K	Y	M	D	S	I	T	C	M	S	L	S	L

BASEBALL
ICE CREAM
SHORTS
LEMONADE
HOT DOGS
PICNIC
POPSICLE
SWIM
SUNNY

CINCINNATI SOIL PROJECT NEWSLETTER

No. 7, Summer 1991

1142 Main St., Cincinnati, OH 45210

PROGRAM PROGRESS REPORT:

This summer will be a busy time for our families and staff. Sherry will be sending appointments to all families to come to our Main Street office in June for the last blood collection.

Our monitoring teams will collect samples for the final time. Also this summer, our focus will be on the Glencoe and Mohawk areas. We will remove and replace lead contaminated soil and clean the streets and other paved areas around Hannah Park and Glencoe Place in Mt. Auburn. Furniture and carpet replacement in the Glencoe and Mohawk neighborhoods is also scheduled.

CALENDAR OF EVENTS:

JUNE 1	Kids Fest (Sawyer Point)
JUNE 6	Last day Cinti Public Schools
JUNE 14	Flag Day
JUNE 16	Father's Day
JUNE 21	1st day of Summer
JULY 4	Independence Day

SUMMER LEAD ALERT:

DIRT & PAINT CHIPS

As summer approaches, our children spend more time outside. Children are exposed to more sources of lead outside playing than they are during the winter months. Lead is often found on painted porches, fences, garages and windows. Lead can be in dust and dirt around old buildings and houses where children play. Infants and young children playing in these areas often put their hands, toys, dirt or even food they drop on the ground in their mouths. These are the most common ways children become exposed to lead.

LEAD POISONING PREVENTION TIPS:

- Discourage thumb sucking
- Keep toys clean of dirt and dust
- Keep areas where paint is peeling or cracking clean by damp moping or vacuuming (daily if needed)
- Good hand washing skills, especially before every meal and snack
- Teach children not to eat dirt or paper

It is very important to have all children between the ages of 1 and 6 years screened for lead at regular clinic visits, usually every 6 months, by a blood test. Early detection will make the problem easier to treat.

SUMMERTIME FUN PLACES:

Over-the-Rhine Community Center
1715 Republic Street
381-1893

•12 and under	free
13 - 17	$5.00 (Dec to Dec)
18 - 54	$6.00 (Dec to Dec)
55 and over	$4.00 (Dec to Dec)

- swimming
- softball--boys and girls
- lunches (free up to 17yrs)
- skating
- tennis
  - -beginners
  - -intermediate
  - -competitive
- Boys Scout and Cub Scout clubs
- arts and crafts
- weekly field trips (planned summer trips)
  - -Indianapolis Children's Museum
  - -Rocky Fork State Park

LeBlonde Boys and Girls Club
1620 Central Parkway
721-7600
Summer programs begin June 10 thru Aug 16
Monday - Friday 10 am to 5 pm
Membership fee $3.00 per year

- swimming
- game room
- gymnastics
- weekly day camps for children of all ages
- lunches served free to children 12 years and under

KID'S FEST
SATURDAY, JUNE 1
10 am to 8 pm
Central Riverfront Area

It's the largest single - day event for children in the country!

Area Highlights

- Showboat Majestic-View "The All American Melodrama".
- River Wharf-Enjoy free riverboat rides.
- Imagination Stations-Join the circus or bounce on a dragon.
- Dinosaur Dugout-Participate in a grand slam of activities with Spike the Dinosaur.
- Sport Court Challenge-Play tennis and sand volleyball.
- Teen Scene-Make music and shoot some hoops.
- Wheels of Fortune-Rollerblade with the Cyclones.
- Kids Talk Radio-Join WCKY for a live broadcast.
- Walk of Fame-Meet the 19XIX stars: Michael and Beth Simpson.
- Our Family of Animals-Become friends with the animals. You get all of this and more. And, it's Free for children and their families.

For more information call the Cincinnati Talking Yellow Pages and enter code 3150. Kids Fest is produced by the Cincinnati Recreation Commission and Media sponsors: 19XIX TV and WCKY Radio Corporate Sponsors: White Castle, Hutch, LaRosa's, BB Riverboats and Frisch's

SUMMER WATER SAFETY:

Warm weather is here! With onset, our children are out and about playing. While enjoying the outdoors, we need to teach our children to think and practice water safety rules. Injuries are the leading health risk facing children today. However, some simple safety measures could lower the risk of an injury or perhaps death. Here are some basic safety rules when your child goes swimming or bathing:

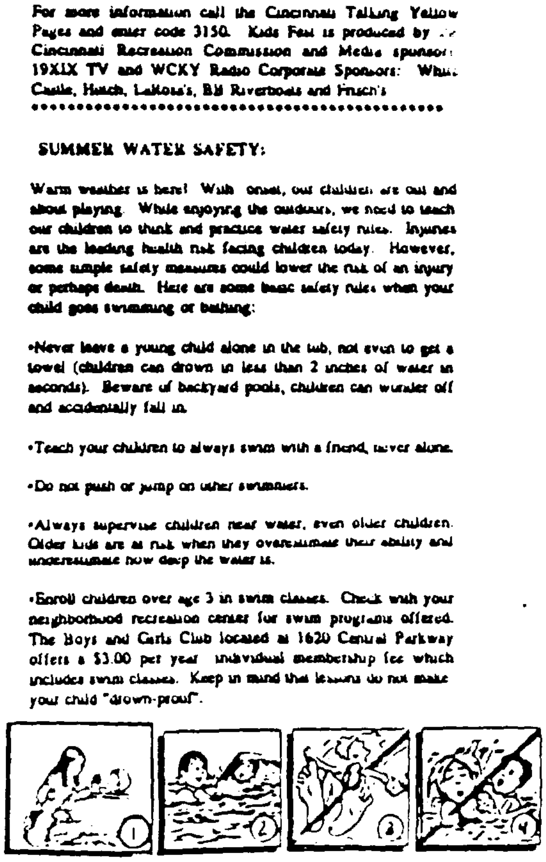
- Never leave a young child alone in the tub, not even to get a towel (children can drown in less than 2 inches of water in seconds). Beware of backyard pools, children can wander off and accidentally fall in.

- Teach your children to always swim with a friend, never alone.

- Do not push or jump on other swimmers.

- Always supervise children near water, even older children. Older kids are at risk when they overestimate their ability and underestimate how deep the water is.

- Enroll children over age 3 in swim classes. Check with your neighborhood recreation center for swim programs offered. The Boys and Girls Club located at 1620 Central Parkway offers a $3.00 per year individual membership fee which includes swim classes. Keep in mind that lessons do not make your child "drown-proof".



ATTACHMENT C

FROM THE DESK OF NURSE DONNA:
INFANT FORMULA VS. BREAST MILK

Because of your baby's rapid growth, at no time is nutrition more important than during infancy. During the first year, particularly during the first 6 months, milk is your baby's primary food. Human breast milk or infant formulas, which are designed to be nutritionally as much like breast milk as possible, are most desirable for babies.

Much of the literature today states that human breast milk is the superior feeding for babies. The "positives" for breastfeeding are as follows: breast milk is easy to digest, it contains the right nutrients in the right amounts, and breast milk helps protect your baby against infections. It is safe, clean, [illegible] likely to cause an allergy, and inexpensive. Many mothers claim that breastfeeding [illegible] special mother-baby [illegible] [illegible] breastfeed. One [illegible] able to stumble [illegible] without having to worry about preparing [illegible] of formula." For moms that work, breast milk can be expressed by means of a breast pump and can be stored in the refrigerator or freezer. Breast feeding can also be supplemented with formula. As an added bonus, nursing helps speed up the contraction of the uterus to its pre-pregnancy size.

When a mother is not breastfeeding, commercially prepared infant formula is used. All formulas available are designed to be nutritionally similar to breast milk, so you can confidently use the brand recommended by your doctor. However, if the formula requires water to be added, it is important to add *only* the amount of water suggested. There is no need to add water to "ready to feed" formulas. Many mothers choose to bottle feed because breastfeeding means being confined. Some mothers want to bottle-feed so that the father can share in this aspect of being a parent.

When deciding whether to breastfeed or bottle-feed, the important thing to remember is to make your own choices. Your approach to feeding may not be the same as your neighbor's or best friend's. But both can be fitting for your particular family. Parents today have several options for providing safe, adequate nutrition.

HAPPY

SPRINGTIME !!!!!

THE CINCINNATI SOIL PROJECT
1142 MAIN ST.
CINCINNATI, OH 45210

A TOUCH OF HISTORY:

February, as we all know was Black History Month. A time when special efforts are extended to every individual regardless of color to broaden their level of education on black historians. Although there have been countless years of education lost, the little we learn should be carried with us forever. In reference to the Afro-American community, it is time to instill in our young children positive role models. There is much that we can do to educate our children in the [illegible] history and to promote positive [illegible] images.

[illegible]

[illegible] Walker invented [illegible] as well as other [illegible] agents for hair. Eventually [illegible] owned her own manufacturing company and made millions in the process.

Charles Drew—saved thousands of lives during WW II because of the efforts made in the conservation of blood plasma.

[illegible] Randolph—worked for 40 yrs to provide higher wages and improve working conditions. Highly opposed to racial discrimination.

[illegible] black entrepreneur who [illegible] during slavery days by [illegible] as a merchant. He was [illegible] middle 1700's.

[illegible] a few. Here's a [illegible] the names of these [illegible] the traffic light [illegible]

-Traci Taylor

FROM SHERRY'S KITCHEN:
Easy Cookies 'n Cream Ice Cream

[illegible] vanilla ice [illegible]

[illegible] of Cool Whip [illegible]

[illegible] pan. Spoon softened [illegible] separate container. Stir [illegible] cookies in a plastic bag and [illegible] using a rolling pin or by hand. [illegible] cookies to ice cream and Cool Whip mixture. Spoon ice cream into a freezer bowl and re-freeze. Enjoy!

CINCINNATI SOIL PROJECT NEWSLETTER

NO. 6, SPRING 1991 — 1142 MAIN ST., CINCINNATI, OH 45210

PROGRAM PROGRESS REPORT:

In the past several months, since our last visit to Soil Project families, our technicians have been busily collecting soil and street dust samples from various locations in the study neighborhoods. These samples will be added to the thousands of other samples collected both inside and outside of homes to help answer questions about lead. During the three years of this study, we expect to collect over 25,000 samples, including street dust, soil, interior dust, paint, [illegible] and handwipe samples from children [illegible] in the study. The information we get from the analysis of these samples will hopefully tell us whether our cleaning activities have reduced the levels of lead in the environment [illegible] blood leads.

Speaking of collecting samples, we will again be visiting some families in about a month. Just as we did last year at this time, we will be collecting water samples and analyzing the paint on the walls in some homes. We will not revisit those homes where we have already collected water and analyzed the paint. We will only visit the homes of new families who were enrolled in the Soil Project during 1990. The next time we will visit all of the families in the Soil Project, will be in the summer of 1991 and that will end the project.

We are now in the process of planning for the cleaning activities for 1991. Our work this year will be in those homes in the [illegible] and [illegible] areas, the areas which have not already received furniture, carpeting and interior cleaning. These two neighborhoods will also receive the exterior abatement during the summer of 1991.

SPRING CALENDER

St. Patrick's Day	March 17
1st Day of Spring	March 20
Easter	March 31
Daylight Savings Time	April [illegible]
Nat'l Volunteer Wk begins	April [illegible]
Arbor Day (in Ohio)	April [illegible]
Memorial Day	May 27

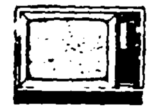
EASTER EGG HUNT!!!

Kahn's/Hillshire Farms Easter Egg Hunt at:

Sawyer Point
Sunday, March 31
Registration 12:00 noon
Egg Hunt 1:00-3:00 p.m.

Children up to 12 yrs old.
WINK radio disc jockey! Prizes! Fun!

THE TV BEAST AND YOUR CHILD:



Has the TV become a problem in your home? Have you ever watched your child watching TV? Have you noticed the trance-like expression on his or her face and asked yourself, "What's my child doing?" Do you use TV to keep your child occupied while you are busy doing something else? We ask these questions because TV has become a substitute parent and teacher [illegible] today.

[illegible] a lot to be learned from TV. However, [illegible] concern about the excessive [illegible] viewing. The problem is that children [illegible] their time wisely and to be [illegible], they often become passive [illegible]. Often children miss out on [illegible] playtime.

By limiting the amount of TV your child watches, you can help create an environment that is free of distractions. You may want to use this time for the reading aloud of storybooks or sharing ideas and experiences. By doing this, you will quickly see your child's imagination and creativity come out. You will be helping them to develop to their fullest potential.

How you limit viewing is less important than just doing it. Don't forget to set a good example by limiting your own watching as well!

BIRTH ANNOUNCEMENTS!

[illegible]AKILA W.	12/06/90
[illegible]TANAE S.	12/07/90
[illegible]	12/26/90

Congratulations and good luck in the future!!

[illegible] School for Creative and Performing Arts [illegible] and dance production:
[illegible] "Leonard Bernstein"
[illegible] April 26-28, 1991
[illegible]

For more information, call the school box office at 632-5910.

FROM THE DESK OF NURSE DONNA REGARDING PREGNANCY AND NUTRITION

Many of us have heard a pregnant mother say " I'm eating for two now, so I'll eat this extra bag of potato chips and candy bar!" It is true that during pregnancy extra calories are required. However, it is the *quality* of calories that count, not the quantity. It is also true that during pregnancy, one has to supply all the nutrients for two. Both the expectant mother and her baby do need more vitamins and milk than other people. However, since the baby is small, the number of extra calories required to accomplish this is only 300 to 500 calories a day. A healthy woman can get most of the vitamins and minerals needed from a well-balanced diet. This includes several servings of fruits and vegetables; such as fruit juices, melons, oranges, broccoli and greens, whole enriched grains; from breads and cereals, proteins; such as beef, eggs, and beans, and four to five glasses of milk a day. No single food contains all the nutrients you and your baby need. Therefore, eating foods from all of the food groups are important.

Listed below are some do's and don'ts regarding pregnancy and nutrition:

YOU DO NEED

SALT - Salt food to taste, unless your doctor tells you different.

LIQUIDS - While pregnant you need at least six 8 ounce glasses a day. This could be water, milk, fruit juices and soups.

FATS AND OILS - At least 2 tablespoons of fats and oils in addition to suggested diet.

IRON AND FOLACIN - You may need to supplement these nutrients with your diet. Check with your doctor about a supplement. Be sure to take vitamins and dietary supplements as your doctor suggests!

YOU DON'T NEED

ALCOHOL - Don't drink. Alcohol can cause your baby to be small and can cause other problems including mental retardation.

DRUGS - Don't take street drugs. Some drugs can cause your baby to be born with an addiction or birth defects. Don't take any medicines such as aspirin without your doctors okay.

CIGARETTES - Smoking can cause smaller babies and smaller babies are more likely to have health problems.

NON FOOD ITEMS - Don't eat things like clay, laundry starch or baking soda. If you feel like eating things that are not foods, tell your doctor.

"JUNK" FOOD - Your baby needs lots of protein, vitamins and minerals, that are not provided by many snack foods.

What YOU eat can make a big difference in the physical and mental development of YOUR BABY. It can also determine whether you will have a normal pregnancy and delivery!

BIRTH ANNOUNCEMENTS

MICHAEL T.	07/30/90
YASMEEN P.	10/07/90
KIERAN G.	10/09/90
AARON B.	10/25/90

FROM LISA'S KITCHEN

CHRISTMAS WREATHS a la RICE KRISPIES

You can devise many holiday treats using the well-known Rice Krispies bar recipe, including these mini-Christmas wreaths.

5 cups Rice Krispies
4 cups mini-marshmallows (or 1 bag of regular marshmallows)
1/4 cup margarine
green food coloring
red cinnamon candies
toothpicks

Melt margarine in 3 quart saucepan, add marshmallows and cook over low heat. Stir constantly until syrupy. Remove from heat. Add green food coloring until mixture becomes a dark green color. Add cereal and stir until well coated. With buttered hands shape mixture into a "doughnut". Cool. Decorate with red candies.

CINCINNATI SOIL PROJECT NEWSLETTER

NO. 5 WINTER 1990 1142 MAIN ST., CINCINNATI, OH 45210

HAPPY HOLIDAYS FROM ALL OF US: BOB, SCOTT, LINDA, SANDY, JOANN, BILL M., BILL H., WINKEY, BELINDA, PENNY, JOYCE, RONNIE, ROSE, PAT, JOHN, JIM, SHARON, RANGA, KATE, TRACI, JESSICA, CARLA, TODD, NORM, RAMONA, TONIA, TANA, KRIS, KELLYE, DENIS, CHRIS, JASON, JIAN LIANG, LISA, DONNA, HERB, DENISE AND SHERRY

WE WISH EVERYONE THE BEST DURING THIS HOLIDAY SEASON AND IN 1991. WE APPRECIATE YOUR COOPERATION IN MAKING THE CINCINNATI SOIL PROJECT A SUCCESS IN 1990 AND WE LOOK FORWARD TO CONTINUED SUCCESS IN 1991.

PROGRAM PROGRESS REPORT:

Early in October we completed the removal and replacement of lead contaminated soil and the cleaning of the streets, parking lots, and alleys in the areas around Findlay Market, Grant Park, and 12th and 13th streets near Reading Road. Part of that cleanup work involved renovation in some of the public parks. In Grant Park we replaced a lot of eroded soil, and we laid new sod and replaced the areas under the play equipment with shredded bark. In the Findlay playgrounds, we replaced the sod and installed new soft play surfaces under the play equipment. The final step in our cleanup process was to clean the streets, sidewalks, alleys and other paved surfaces in those areas where we completed the soil removal and replacement.

Now that we have completed the 1990 soil removal and replacement and dust cleanup, our monitoring staff will be responsible for collecting soil and street dust samples. The purpose of collecting the samples is to check to see if the lead was removed and to see if the cleaned areas become recontaminated with lead from other parts of the city. Because of the need to do this, you will very likely see our staff collecting those samples on days when weather permits through the end of January. After that they will work in the labs processing the samples getting them ready for analysis.

In the spring and summer of 1991 we look forward to completing the abatement and collecting the final samples necessary to complete the soil project.

THE CINCINNATI SOIL PROJECT HOLIDAY SCHEDULE

CHRISTMAS EVE -Monday, December 24

CHRISTMAS DAY-Tuesday, December 25

NEW YEAR'S DAY-Tuesday, January 1

DR. MARTIN LUTHER KING'S BIRTHDAY-Monday, January 21

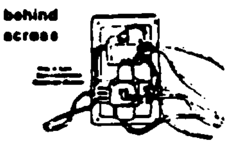
CHRISTMAS TRADITIONS:

SANTA CLAUS

About 100 years ago, the Santa Claus as we know him today was created. He is short and plump with red cheeks. He dresses in red clothing with white fur trim and he travels with a team of reindeer and a sleigh. This is America's contribution to the Santa Claus tradition. Up until this time this old white bearded man was know as St. Nicholas. He was dressed in a black robe and rode on a gray mare, and his day of celebration was December 6.

HOLIDAY SAFETY TIPS:

1. Keep the base of your Christmas tree wet.
2. Use only UL approved Christmas lights or appliances.
3. Check Christmas lights for frayed or worn wires.
4. DO NOT leave your Christmas lights on when you leave the house.
5. DO NOT overload electrical cords or outlets.
6. NEVER run wires under rugs, behind radiators, over doorways or across walkways.



WINTER SAFETY TIPS:

1. Keep portable heaters away from curtains and other flammable materials
2. Be sure your heater is in good working condition. All room heaters need frequent checkups and cleaning. A neglected heater is a critical fire hazard.
3. Avoid using electric space heaters in bathrooms, and do not touch one when you are wet.
4. Keep young children away from space heaters, especially if they are wearing a nightgown.
5. NEVER use a gas range or an oven to heat your kitchen.
6. DO NOT leave lit oven doors open. Children could burn themselves on the door or heating element.
7. If windows are emergency exits in your home, train your family how to use them in case fire should strike. See to it that storm windows open and that they are not blocked by objects.

ATTACHMENT A

THE CINCINNATI SOIL PROJECT NEWSLETTER

NO. 8, FALL 1991 1142 MAIN ST, CINCINNATI, OH 45210

PROGRAM PROGRESS REPORT:

1991 is the year for interior and exterior clean-up activities in the Glencoe and Mohawk areas. As the leaves begin to turn in the fall, we are in the process of completing our final clean-up activities in Hannah Park. Information gathered during the Soil Project Study, hopefully, will tell us whether our cleaning activities over the last three years has lower blood lead levels.

We appreciated your participation in our project and want to say "thank you". It was terrific having families that are committed to improving child health in our study.

It was a pleasure to see everyone who attended the family meeting held at Sawyer Point in August.

CALENDAR NOTES

OCTOBER

6-12	FIRE PREVENTION WEEK
14	COLUMBUS DAY
19	SWEETEST DAY
24	UNITED NATIONS DAY
31	HALLOWEEN

NOVEMBER

5	ELECTION DAY
11	VETERAN'S DAY
28	THANKSGIVING DAY

KEEP YOUR GHOST AND GOBLINS SAFE

We all know the enjoyment our little ones get from Halloween, dressing up and going out to collect their tricks and treats.

This Halloween let's keep safety in mind while preparing to send our children out to take part in this fun.

1. Be sure the child's costume fits properly, so that the youngster has no problem with walking or moving their arms about freely.

2. If wearing a mask, be sure the child has proper eye and nose openings.

3. If the costume requires any decoration other than on the clothing (things to carry) see that it is light weight and safe for your child to walk with.

4. If your area's trick or treat time will be during dusk or dark, a small flashlight would be helpful.

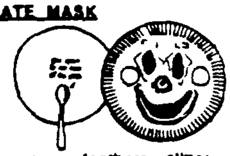
5. **NEVER** allow your child to "Trick or Treat" **ALONE.**

6. Talk to your children about the importance of staying with the group and avoiding strangers.

7. When your child returns home, go through his/her trick or treat bag and through away anything which looks to have been tampered with. (Anything that is not individually store wrapped)

By following these tips a SAFE and FUN Halloween can be had by everyone!

PAPER PLATE MASK



You will need:
paper plate
non-toxic felt-tip pens
scissors
plastic spoons
tissue paper, construction paper, feathers, glitter, felt scraps, etc

What to do:

1. Hold the plate to your face and ask a parent, older brother or sister or friend to mark where your eyes and mouth are.

2. Cut out the holes where the marks are.

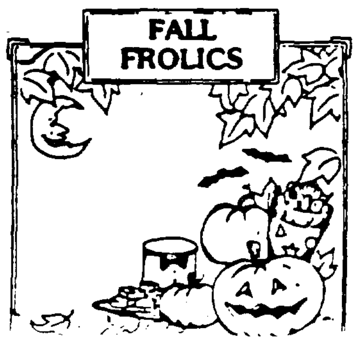
3. Decide what character you want to be and design your plate to look that way. (a cat, dog, clown or scary witch)

4. Glue the a spoon to the back of the plate so it can be used as a handle to hold your mask up or have a parent make a small hole on both sides of your face you made a put a string through them that will fit over your head so you do not have to hold it up.

WORD SEARCH

A	B	E	I	P	N	I	K	P	M	U	P	T	L	Y
C	D	F	Y	R	A	C	S	E	Q	H	U	R	F	C
I	J	K	N	P	S	R	N	O	M	K	M	W	D	B
U	F	L	A	S	H	L	I	Q	T	W	P	B	T	N
Q	T	A	C	K	C	A	L	B	V	S	K	S	A	M
O	M	X	G	Y	W	E	B	R	P	V	I	L	U	Q
H	Q	K	H	A	L	L	O	W	E	E	N	P	Y	O
O	O	I	O	H	O	E	G	N	A	M	A	W	D	A
R	N	N	S	E	W	R	H	B	O	A	I	R	N	T
S	E	D	T	R	I	C	K	O	R	T	R	E	A	T
E	A	S	Y	E	T	L	R	V	C	W	I	T	C	H
A	E	H	E	O	C	B	X	H	V	B	N	M	A	F
G	M	A	A	B	H	E	B	N	E	V	R	A	C	G

BLACKCAT	GHOST	PUMPKIN
BROOM	GOBLINS	PUMPKIN PIE
CANDY	HALLOWEEN	SCARY
CARVE	MASKS	TRICK OR TREAT



WHAT YOUR CHILDREN AND YOU SHOULD DO IN CASE OF FIRE:

The month of October is designated as national fire safety month. Fire fascinates children. Even if they know it is dangerous, they are amazed by flames.

Teach your children what to do in a fire:

1. **GET OUT FAST, SECONDS COUNT.** Phone for help from a neighbor's home, not from inside a burning building.

2. **CRAWL LOW** under the smoke.

3. **TEST** the door. If it is hot or there is smoke, use another way out.

4. **ONCE OUTSIDE, STAY OUT.** There is nothing more important in your home than you.

IF CLOTHING CATCHES ON FIRE:

Some children falsely believe that their clothes will protect them from fire. Show children, age 3 and older, what to do if their clothes catch on fire. Practice with them.

1. **STOP.** Running fans the flames, making the fire burn faster. **SHOUT** for help. Don't run for help.

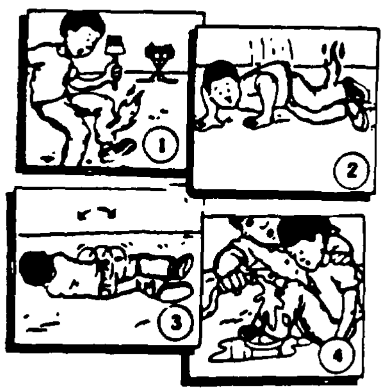
2. **DROP** to the floor. Cover your face.

3. **ROLL** back and forth to put out flames.

4. **COOL** a burn with cool water.

TEACH YOUNG CHILDREN THAT:

-Matches and lighters are tools for adults, not toys.
-Children who play with matches or lighters can be badly burned and can hurt others.
-If they find matches or lighters, tell an adult the location right away.



THANKSGIVING...and HOW IT STARTED

We celebrate Thanksgiving as a cultural holiday and a religious observance. Abraham Lincoln was the first President to issue a proclamation marking the last Thursday in November our annual Thanksgiving Day. In 1941 the day was officially declared a national public holiday. The traditional turkey and pumpkin pie may have their beginnings in the Thanksgiving Day of the early American settlers, but the idea of celebrating the completion of the harvest and rendering homage to the spirits is an ancient custom that is still practiced in may foreign lands. Although some part of this American holiday finds many men watching football games and many women in the kitchen preparing foood, families are united at the dinner table for the traditional festive meal - a gathering reaffirms family ties.

....

RECIPES FOR EVERYONE:

EASY PUMPKIN PIE

1	large can of pumpkin
1	can of evaporated milk
2tsp	pumpkin pie spice mix (or to taste)
2	eggs
3/4 cup	sugar
1/2 tsp	salt
1	frozen 9 inch pie crust

Thoroughly mix pumpkin, canned milk, eggs and pumpkin pie spice together. Add sugar and salt. Pour into pie crust. Preheat oven to 425° and bake for 15 minutes, reduce heat to 350° and continue to bake for another 45 minutes or until you can stick a knife in the center of the pie, pull it out and the knife comes out clean. Let pie cool completely before serving and if desired put cool whip on top of pieces when serving. ENJOY!!!

JACK-O-LANTERN PIE

1 pkg	orange jello (4 serving size)
1 cup	boiling water
1 pint	vanilla ice cream
1 pkg	chocolate crumb pie crust
1	small container of cool whip
	candy corn
	black licorice cut into strips

Dissolve jello in the boiling water. Stir in ice cream until thoroughly mixed. Place in freezer for 10 minutes. Remove from freezer and pour into pie crust, place in refrigerator for 2 hours. Before serving cover with cool whip and use candy corn and licorice to make a jack-o-lantern face on the pie. The children will love it.

HAPPY HOLIDAYS!!!!

....

U.C. DEPT. OF ENVIR. HEALTH
THE CINCINNATI SOIL PROJECT
1142 MAIN STREET
CINCINNATI, OHIO 45210

APPENDIX E

Institutional Review Board-approved Consent and Release Forms

Family I.D. ________
Child I.D. ________

INFORMED CONSENT STATEMENT
UNIVERSITY OF CINCINNATI MEDICAL CENTER
Soil and Dust Abatement Study

1I. INTRODUCTION

Before you agree to participate in this study, it is important that the following explanation of the proposed procedure be read and understood. It describes the purpose, benefits, risks and discomforts, and precautions of the study. It also decribes the right to withdraw from the study at any time. It is important to understand that no guarantee or assurance can be made as to the results. It is also understood that refusal to participate in this study will not influence standard treatment for the subject.

II. PURPOSE OF STUDY

I, ________________________________ agree to participate in a medical study the purpose of which is to determine the amount of lead in my blood or that of my child (children), ____________________________ Also, my home will be surveyed to identify possible sources of lead in soil, dust, paint and water. This information will be used to examine the effectiveness of dust and soil lead removal methods.

III. PROCEDURES AND RISKS

I have been told that the blood sample obtained will be measured for lead. A small amount of blood, about one teaspoon, will be drawn in order to permit measurement of lead and related measurements such as iron. I know that my child may cry for a moment when his/her finger or arm is pricked to obtain blood for the lead measurement. The risk of simple venipuncture include: commonly, the occurence of discomfort and/or bruise at the site of puncture; and less commonly, the formation of a small blood clot or swelling of the vein and surrounding tissue, and bleeding from the puncture site. If I am a woman and I am or should become pregnant, there is no risk to me or my fetus by participating in the study. My blood will be drawn once. My child's blood will be drawn five times at six month intervals. I have also been told that no risks are associated with the survey of my residence for lead sources or with procedures used to reduce the amount of lead in soil and dust around my home. I will be participating in the protocol for approximately 2 years or until I move from my current residence, which ever comes first. If there is a significant variance from the stated time period, I will be notified.

IV. BENEFITS

Several benefits arise as a result of my participation on this study. First, I will be notified of the blood lead results. Second, the health department will be notified if high blood levels are found so that appropriate actions can be taken. Certain environmental improvements, such as street cleaning and playground improvements may also occur in my neighborhood.

Family I.D. ________

V. CONFIDENTIALITY OF RECORDS

All information gathered will be kept private and confidential(my and my child's records will be identified by a code number which will be available only to the study investigators). This information will not be made available to anyone not connected with the study without my permission.

VI. AVAILABILITY OF INFORMATION

Any questions that I may have concerning any aspect of this investigation will be answered by Dr. Scott Clark or an associate at 558-1749

VII. COMPENSATION

The University of Cincinnati Medical Center follows a policy of making all decisions concerning compensation and medical treatment for injuries occuring during or caused by participation in biomedical or behavioral research on an individual basis. If I believe I have been injured as a result of research, I will contact Dr. Scott Clark at 558-1749 or Dr. John Vester, Chairperson, U.C. Medical Center Institutional Review Board at 558-5259.

VIII. FISCAL RESPONSIBILITY

Funds are not available to cover the costs of any on-going medical care and I remain responsible for the cost of non-research related care. Tests and studies done soley for the purpose of research will be paid for from research funds and I should not be billed for them. Blood sampling will take place at a clinic near my home. I understand that I will reimbursed $10 for expenses incurred in bringing my child to the clinic. If I have questions about my medical bill relative to research participation, I may contact Dr. Scott Clark.

IX. THE RIGHT TO WITHDRAW

I am free to withdraw from this survey at any time. Should I wish to withdraw, I have been assured that standard therapy for my child's condition will remain available to me. I have been informed of the probable consequence of my withdrawal from the study. Withdrawal should be made in writing and a form will be given to me for that purpose.

X. Are you (or your child) currently participating in another study?

☐ Yes ______________________; ______________________
Investigator　　　　Title of study

☐ No

Consent and witnessing:

Subject: ______________________ Date: ________
Caregiver (legal guardian): ______________________ Date: ________
Investigator: ______________________ Date: ________
Witness: ______________________ Date: ________

Copies: Investigator's file, and subject or legal guardian.

Release of Medical Information

I authorize The Cincinnati Soil Project to release the following Blood Collection results: Blood Lead and EP, Hematocrit and Hemoglobin and Iron Studies to the Women Infant and Children (WIC) office, physicians and health care agencies involved in our medical care.

The following child/children and myself (Caregiver) shall be covered under this release:

____

____

____

____

____

This authorization will remain in effect until such time as revoked in writing by me.

Caregiver's signature	**Soil Project signature**
DATE	**DATE**

CONSENT TO WITHDRAW FROM STUDY

DATE: ________________

I, ____, wish to withdraw my child,

____, from the medical study.

I have been informed that at the present time my child's blood lead level is Normal/Elevated/Unknown*. I have also been told that it is important that I continue to take my child to a clinic for routine medical check-ups, and to have his/her blood checked for lead at least every ________ months.

Consent and Witnessing:

____ Date: ______________________
Mother/Caregiver

____ Date: ______________________
Investigator

____ Date: ______________________
Witness

Copy to: Mother/Caregiver
Investigator
Child's Chart

* INASMUCH AS YOUR CHILD'S BLOOD WAS NEVER DRAWN, HIS/HER BLOOD LEAD LEVEL IS UNKNOWN.

APPENDIX F

Interior Dust Clean-up Methods Development Manuscript

"Clean-up of Lead in Household Carpet and Floor Dust"

A manuscript submitted for publication to the American Industrial Hygiene Association Journal.

Clean-up of Lead in Household Carpet and Floor Dust

Lynda Ewers[1,2], Scott Clark[1]*, William Menrath[1],

Paul Succop[1] and Robert Bornschein[1]

[1]Department of Environmental Health

University of Cincinnati, Cincinnati, OH 45267-0056

[2]**PRESENT ADDRESS:**

National Institute for Occupational Safety and Health

Cincinnati, OH 45226

*Corresponding Author

Abstract

Effective methods to remove lead-containing dust from household carpets and other floor areas are necessary to reduce exposure of young children to dust lead from household paint as well as that entering the home from other sources. Since such methods were not available in the literature it was necessary to develop them for use in a Superfund-supported soil and dust lead abatement demonstration project. Methods were tested on carpets obtained from homes of children with high blood lead and on new carpets artificially-contaminated in the laboratory using an ASTM method. Carpets removed from these homes were not able to be cleaned effectively in the laboratory by repetitive cleaning with HEPA filtered vacuum cleaners. The lead concentration in the removed dust remained about the same from the initial cleaning (1 min/sq.m.) to the final cleaning (total cleaning time of 10 min/sq.m.). The lead loading on the surface of the carpets often increased during the cleaning process due to the action of the vacuum cleaner in bringing to the surface lead from deeper in the carpet. For bare wooden floors over 95% of the total dust removed by the combination of dry vacuuming (5 min/sq.m.) followed by wet washing was removed by the dry vacuuming. For linoleum, more than 75% was removed by vacuuming for 5 min/sq.m. However little was removed in vacuuming after the initial two minutes and about 20%

was removed in the final wet washing step. HEPA vacuuming of the new laboratory-contaminated carpets revealed that two of the commercially-available vacuum cleaners tested were essentially equivalent and each removed significantly more dust than a third vacuum cleaner during a cleaning process of a total duration of 10 min/sq.m. Cleaning for 6 min/sq.m. was necessary to remove more than 70% of the embedded dust by the two more efficient vacuum cleaners. Cleaning efficiencies were about the same for short pile and sculptured carpets.

Based on this research and recent reports from others developing similar methods, it was concluded that in many situations it was more practical to replace the carpets rather than to perform costly and only partially-effective cleaning procedures. HEPA-vacuuming cleaning of carpets was shown to increase lead-dust on the surface under some conditions.

The reduction of young children's lead exposure is one of the nation's most important environmental health goals. Many investigators have concluded that lead-contaminated house dust is a critical link in the exposure pathway, resulting in elevated blood lead of young children. The lead contaminants in dust are primarily derived from lead-based paints which were former widely used on both the interior and exterior of housing. Lead dusts can also enter housing from areas outside the home with lead-contaminated dust and/or soil, as well as through lead-containing dust carried home from the workplace. A typical exposure scenario involves lead in exterior dust, from soil and paint, contributing to lead in interior floor dust, which is then picked up on the hands of children, where it is subsequently ingested resulting in elevated blood lead. The childhood lead exposure pathway model that has been developed for Cincinnati and other areas is summarized in Figure 1[1-6] suggest that residential lead abatement activities should include the cleaning of locations in the house where lead-contaminated dusts are present, such as carpets and other floor areas.

Because of the known relationships between interior dust lead and blood lead, interior dust abatement was included in the exposure reduction strategies of the Cincinnati Soil Lead Abatement Demonstration Project. This project was one of three carried out under a provision in the Superfund Amendments and Reauthorization Act (1986) which called for a "... pilot program for removal, decontamination, or other action with respect to lead-contaminated soil in one to three different metropolitan areas". Interior dust abatement is also an important consideration as an essential component of lead-based paint reduction strategies. The U.S. Department of Housing and Urban Development (HUD) has acknowledged the importance of lead-dust in its Interim Guidelines for Lead-Based Paint Abatement[7] and has recommended the removal of furnishings, including wall-to-wall carpeting, prior to abatement. Recommendations for the cleaning of furnishings such as carpets and furniture prior to their being returned to the abated dwelling unit are not yet included in HUD guidelines. These items may well have been contaminated prior to the lead-based paint abatement process, and therefore placing them back in the housing will only reintroduce an exposure source to the otherwise cleaned housing.

A search of the literature revealed only a single paper systematically documenting efforts to remove lead-dust contamination from carpets.[8] Milar and Mushak[8] concluded that a two-part steam cleaning, initially using a sodium hexametaphosphate commercial cleaning product, followed 24 hours later by steam cleaning using a commercial detergent, removed about 60% of the lead-dust expressed as a surface loading basis and reduced the lead concentration by 30 to 50%.

In a previous publication we reported results of a preliminary evaluation of Milar and Mushak's[8] procedures, with the additional step of dry-vacuuming with a HEPA-equipped vacuum cleaner. The test was carried out in several homes contaminated by worker take-home of lead-contaminated foundry dust.[9] Although these vacuum and shampooing procedures can remove <u>some</u> of the lead-containing dust from carpets, it is important to know whether these methods reduce the amount of lead dust at the surface (mg Pb/sq.m.) where it is most available to children. (Normal vacuuming will tend to redeposit below surface dust through bringing it to the surface from deeper in the carpet and through non-filtration through vacuum cleaner bags of high porosity.) These methods were found to either have only limited impact on, or even <u>increase</u> surface loading as determined by an exposure-related sampling method developed by Que Hee <u>et</u> <u>al</u>. Repetitive dry vacuuming was also previously evaluated on three carpets in a routinely-cleaned suburban home where exterior paint sanding had occurred sixteen months earlier.[9] In this latter case surface dust on an area or loading basis (μg Pb/sq.m.) decreased with vacuuming by between 64 and 94%. These experiences suggested that cleaning "chronically-contaminated" carpets (those which received lead dust over an extended period of time, could actually increase the likelihood of lead exposure, whereas cleaning of "acutely-contaminated" (i.e., from a single episode) carpets may be effective in reducing exposure. Based on preliminary work, it was concluded that additional development of surface dust abatement methods was needed, particularly for heavily-contaminated carpets. There was also a need to determine the efficacy of the variety of HEPA vacuum cleaners available, the length of cleaning time necessary to significantly reduce lead loading, and the variability in the effectiveness of cleaning among different workers.

METHODS

Two dust collection methods were used to measure the effectiveness of cleaning. The first used the contents of the HEPA vacuum cleaner paper bag as a measure of the total amount of removed dust and lead. The second was a surface dust vacuum method previously developed by Que Hee et al.[10] and which has been shown to produce results which correlate with exposure as measured by blood lead.[1-6] The usefulness of the vacuum cleaner as a sampler depends, in part, on whether the vacuum cleaner removes a satisfactorily large proportion of the available dust.

The method of Que Hee et al.[10] utilizes a light-weight, battery-operated personal air sampling pump (2 liters per minute) to collect dust in a filter holder while sampling over a known area. This method, known as the "dust vacuum method", was not designed to determine the total dust lead on a surface, or within a carpet but it was intended to collect the dust most readily available to a young child.

Two sources of contaminated carpets were used: (1) contaminated carpets removed from homes of children with high blood lead; and (2) new carpets with artificial dust embedded in them a laboratory setting. The variations in effectiveness of different available vacuum cleaners and operators on different carpet types were examined in the new carpets contaminated in the laboratory. The effectiveness of methods for cleaning linoleum and unpainted wood floors with different surface types was also evaluated. Data were analyzed using the Statistical Analysis System.[11]

Laboratory Cleaning of Contaminated Carpets

Thirteen existing carpets from inner-city homes, several where children had been lead poisoned, were removed and replaced with new carpets and brought to the laboratory for testing. Ten cleaning "efforts", each defined as cleaning with a HEPA filter equipped vacuum cleaner at a rate of one minute/square meter, were performed on one square meter areas of each carpet. Thus, each carpet was cleaned for a total of ten (10) minutes per square meter. The extent of cleaning was chosen to be length of time of cleaning and the unit rate of cleaning was chosen to be one minute per square meter of carpet. This rate was also convenient for manipulating the nozzle in a systematic way. The pattern used was three up/back passes with the nozzle over the area. The size of the "beater bar" nozzle was sufficient to just allow coverage, within one minute, of a one square meter area in these three passes with very little overlap. This complete coverage of a square meter in three up/back passes at a rate of 1 minute/square meter is called "one cleaning effort". Preliminary studies confirmed reports from industry sources[13], that a nozzle with a rotary "beater bar" driven by an independent motor was more effective than a nozzle without a "beater bar". A readily-available commercial beater bar nozzle (Sears Kenmore) was used for the cleaning. The weight and content of the vacuum cleaner dust bag were obtained after successive cleaning efforts. Surface dust measurements were collected using the method of Que Hee et al.[10] at two pre-determined locations on each of the carpets before cleaning commenced, and after the first, third and tenth cleaning efforts were completed.

Equipment, Operator, Loading and Carpet Variability

In-laboratory cleaning of new carpets with artificially embedded dust using a modified version of ASTM procedure F 608-86[12] was used to determine the effects on cleaning performances of equipment, loading, carpet type and operator. This ASTM procedure specifies the method of imbedding a test dust mixture into the new carpet prior to their being subjected to the vacuuming protocol. The experimental design included three HEPA vacuum cleaners, two carpet types (sculptured and short pile), two dust loadings (100 and 400 g/sq.m.) and two operators.

The test dust mixture was made up of 100 g and 400 g allotments and consisted of a sand and talc mixture in a 8:1 ratio. The talc was a USP Grade Supreme Talc purchased from a local supplier. Ninety-five percent of the Keener sand used was retained in the 210-299 μm size fraction. The two components of the test dust mixture were weighed and mixed individually before each test.

A one square meter surface area in the center of each carpet served as the test area. The carpets were preconditioned as specified in the ASTM procedure by adding test dust to their surface and removing it by vacuuming until <2 g of material was removed in a cleaning effort. Repeated trials of each carpet type were conducted on the same square of carpet. For each test, the carpet was affixed to a piece of plywood. The appropriate amount of dust was spread onto the delineated area and was embedded into it by dragging an embedment tool (as described in the ASTM procedure)[12] over it for 30 strokes, alternating directions forward and back.

Three commercially-available vacuum cleaners were used (see Table 1 for details). Each of these was intended for industrial use and had three levels of filtration. The initial filtration level was similar to a home vacuum cleaner in that a removable paper bag catches most of the dust. The second level of filtration consisted of a more permanent cloth filter. This filtration level does accumulate dust over a period of time but was not found to need changing over the period of these trials. The third layer of filtration was a HEPA filter which removed the remaining fine material and also did require changing during the study.

A readily-available commercial (Sears Kenmore) "beater bar" nozzle was substituted for the nozzles provided with the three types of vacuum cleaners. Preliminary studies led to the

Table 1

Vacuum Cleaners Tested

Cleaner	Model	Cubic Feet Per Minute	Water Lift, Inches
A	Nilfisk GS80	87	75
B	WAP 767	100	90
C	Euroclean UZ930	77	85

conclusion that the "long" pile setting for the nozzle always gave the best cleaning regardless of the actual pile length. This setting was the only one used in these experiments.

The Cleaning Effort

Ten cleaning efforts were performed in each trial. Two experienced operators of the vacuum cleaners were used. The number of different types of carpets, vacuum cleaners, dust amounts, and operators made it impractical to perform cleaning trials for each possible combination of these factors.

Consequently, a randomized, incomplete block design was used. Randomization of both treatment combinations to blocks and the ordering of the treatment combinations was performed. The 24 treatment combinations were randomized to 3 blocks of 8 treatment combinations each. Two of these three blocks were randomly selected to be performed in the experiments.

Analysis

The dependent variable in these experiments was the amount of the test dust collected in the vacuum cleaner bags after 1, 2, 3, 4, 5, 6, 7-8, and 9-10 cleaning efforts.

Statistical analysis was performed by the General Linear Model (GLM) procedure of Statistical Analysis System.[11]

Bare Floors

In order to test the effectiveness of proposed bare floor cleaning procedures, homes with high levels of lead in the dust were needed. Such homes were located through another research project studying lead's neurobehavioral effects on young children.[1] A list of homes meeting the following criteria was compiled:

(1) High lead concentrations in the interior dust;

(2) Either carpet, vinyl, or wood flooring or a combination of those flooring types.

Permission from study participants was obtained to test cleaning methods on different wood and vinyl floors.

The questions to be answered in these homes were:

(1) In order to reduce dust lead to an acceptable level with a HEPA-equipped vacuum cleaner, what rate of speed should the operator use and how many times should the floor be vacuumed?

(2) Does wet washing after the final vacuum cleaning remove additional lead?

The testing procedure was as follows:

(1) Three separate squares, each one meter by one meter, were delineated on the surface of the floor type being tested.

(2) A bag for a HEPA-equipped vacuum cleaner (Nilfisk) was tare-weighed and installed.

(3) The three squares were then vacuumed with the vacuum cleaner at the rate of one minute for each square meter.

(4) The vacuum bag was removed and weighed after each cleaning.

(5) The process was repeated until the three squares were cleaned a total of five times.

(6) Each of the squares was then washed with 1,500 ml of tap water from the residence. The washing was performed with a new sponge by a researcher wearing rubber gloves. An aliquot of 500 ml was taken from each of the wash buckets. A 500 ml sample of clean water from a wash bucket was also collected to provide data on background lead levels in the tap water.

All the dust samples and water samples were analyzed for lead concentration in a laboratory that was participating in a proficiency program established for environmental lead samples by

EPA through its Environmental Monitoring and Support Laboratory (Las Vegas). The samples collected by the dust vacuum method were digested using hot nitric acid and analyzed by a flame AA method with a detection limit of 0.1 μg lead. Dust samples collected in vacuum cleaner bags were sieved at 250 μm and analyzed by XRF (detection limit 20 ppm). Water samples were analyzed by graphite furnace AA (detection limit 1 ppb).

RESULTS

Laboratory Cleaning of Contaminated Carpets Collected from Homes of Inner-City Children

The amounts of lead removed (mg/sq.m.) by the HEPA vacuum cleaners at each measurement interval are presented in Table 2. The cumulative percentages removed, based on the total amount removed after ten cleanings, which was assigned a value of 100%, are also shown. The amount of lead removed by ten cleaning efforts averaged 278.7 mg/sq.m. with a range of 8.6 to 1107.3. Four cleaning efforts resulted in an average cumulative percentage removal of 74% of the total amount removed with a range of 61-89%. Lead concentrations of the material removed from the HEPA vacuum cleaner bags were significantly different between carpets ($p < 0.05$) (Figure 2) ranging from 192 to 3226 μg/g but did not vary significantly from first to last cleaning efforts for individual carpets. Thus, the HEPA vacuum cleaner did not appear to preferentially remove dust with either high or low lead concentration.

A comparison of the initial surface dust lead loading by the method of Que Hee et al.[10] with the total amount of lead removed by 10 minutes/sq.m. cleaning with a HEPA vacuum cleaner revealed that the surface dust lead loading was an average of 1.4% of the total dust lead removed by extensive vacuum cleaning (range 0.12 to 3.3) (Table 3).

Surface dust lead levels (expressed as mg Pb/sq.m.), were also determined before cleaning and after the first, third and tenth cleaning efforts. The ratio of the surface dust lead levels after the first, third or tenth cleaning efforts, to the surface dust lead levels before the initial cleaning (Table 4) revealed that surface loadings, on average, decreased with cleaning. However, in several instances, surface loading increased by up to almost four-fold. These data reveal that vacuum cleaning if not

Table 2

Lead (mg/sq.m.) and Cumulative Percentage[a] Removed by Successive HEPA Vacuum Cleaning Efforts[b] of One Minute Per Square Meter on Carpets Removed from Homes of Children with High Blood Lead

Carpet[b]	1st Effort		2nd Effort		3rd Effort		4th Effort		5-10th Effort	
	mg/ m^2	(Cumu. %)	mg/ m^2	(Cumu. %)	mg/ m^2	(Cumu. %)	mg/ m^2	(Cumu. %)	mg/ m^2	(Cumu. %)
A	10.5	(59)	2.6	(74)	1.0	(79)	0.9	(84)	2.8	(100)
B	159.6	(63)	36.1	(78)	18.6	(85)	9.5	(89)	28.9	(100)
C	294.9	(27)	244.4	(49)	134.9	(61)	90.4	(69)	342.7	(100)
E	70.2	(24)	42.2	(39)	36.8	(51)	28.6	(61)	113.6	(100)
F	32.7	(45)	9.8	(59)	6.1	(68)	4.2	(73)	19.3	(100)
H	18.9	(27)	7.8	(36)	7.6	(48)	8.8	(61)	27.7	(100)
I	2.2	(26)	1.7	(45)	0.8	(55)	0.8	(64)	3.1	(100)

((

Table 2 (continued)

Carpet[b]	1st Effort mg/ m^2	1st Effort (Cumu. %)	2nd Effort mg/ m^2	2nd Effort (Cumu. %)	3rd Effort mg/ m^2	3rd Effort (Cumu. %)	4th Effort mg/ m^2	4th Effort (Cumu. %)	5-10th Effort mg/ m^2	5-10th Effort (Cumu. %)
J	353.4	(60)	51.2	(68)	45.1	(76)	35.8	(84)	95.1	(100)
K	19.8	(48)	6.3	(64)	2.5	(70)	4.2	(80)	8.3	(100)
Averages	106.9	(42)	44.7	(57)	28.2	(66)	20.4	(74)	71.3	(100)

[a]Based on total amount removed in ten cleaning efforts assigned a value of 100%.

[b]Insufficient data available to include carpets D, G, K and L.

Table 3

Comparison of Surface Dust Lead Loading with Total Lead Removed by Vacuum Cleaning for Ten Minutes Per Sq Meter of Carpet[a]

(10 Cleaning Efforts)

Carpet	Initial Surface Dust Lead Loading mg/sq.m.	Total Lead Removed by HEPA Vacuum mg/sq.m.	Initial Surface Lead as a Percent to Total Lead Removed
A	0.591	17.8	3.3
B	5.65	252.7	2.2
C	2.34	1107.3	0.2
E	4.47	291.4	1.5
F	0.186	72.1	0.26
H	0.774	70.8	1.1
I	0.301	8.6	3.5
J	3.87	589.6	0.06
L	0.114	97.8	0.12
Average	2.03	278.7	1.4

[a]Carpets tested were from homes of children with high blood lead.

conducted for a sufficient time, has the potential for increasing childhood exposure. In none of the carpets tested was the surface dust lead loading after ten cleaning efforts as high as it was prior to cleaning.

Table 4

Ratio of Surface Dust Lead Loading (mg Pb/sq.m.) After Specified Number of Cleanings as a Fraction of the Initial Pre-Cleaning Surface Dust Lead Loading[a]

	After First Cleaning	After Third Cleaning	After Tenth Cleaning
Average	0.55	0.47	0.20
Range	(0.11-1.72)	(0.06-3.93)	(0.06-0.61)
% > 1.00	14	5	0

[a]Carpets tested were from homes of children with high blood lead.

Variations in Cleaning Performance of Vacuum Cleaners, Carpet Types, Dust Loadings and Operators

A statistical analysis of the effects of vacuum cleaner type, laboratory-embedded dust amount, and changes in amount of dust collected during successive cleanup and interaction, is presented in Table 5. Statistically significant differences were

Table 5

Final Model - ANOVA of Amounts Synthetic Dust

Recovered in Repeated Vacuuming of Carpets

Source	df	F-Value	PR>F
Between Subject Effects			
Vacuum Cleaner	2	15.11***	0.0005
Dust Amount	1	20.32***	0.0007
Within Subject Effects			
Repeated Dust Weight	7	268.72***	0.0001
Repeated Dust Weight-Vacuum Cleaner	14	2.30**	0.0101
Repeated Dust Weight-Dust Amount	7	2.50**	0.0222

**Significant at $\alpha = 0.05$ level

***Significant at $\alpha = 0.01$ level

observed between vacuum cleaners, amounts of embedded dust and in amounts of dust collected during successive cleaning efforts.

The results of the cleaning of new carpets containing laboratory-embedded dust are presented in Table 6 (a-c) as the mean proportion of the embedded dust removed by the ten cleaning efforts for each of the three different vacuum cleaners, two carpet types and two dust amounts used. Two of the three vacuum cleaners (A and B) removed a statistically higher proportion of the dust than the third (C). Contrasting the performance of the vacuum cleaners (Table 6a), indicated no statistically significant differences between the amounts of dust removed by vacuum cleaners A and B. Results for vacuum cleaners A and B were different from those for cleaner C for all cleaning effort (Figure 3). None of the cleaners removed an average of more than about one-fourth of the embedded material with the first cleaning effort (one minute per square meter of cleaning). Three cleaning efforts (three minutes per sq.m.) were required to remove one-half of the dust for two of the cleaners (A and B) while twice as long (6 min/sq.m.) was required for the third vacuum cleaner (C).

Vacuum cleaner C did not do as well as either A or B beginning with the first cleaning efforts (Table 6a). Although somewhat more dust was removed during the first five cleaning efforts for short pile carpets than for sculptured carpets, slightly more was removed during later cleaning efforts from sculptured carpets (Table 6b). These small differences in dust removal between the carpet types were statistically significant only for the first cleaning effort. A larger proportion of dust

Table 6

Proportion of Total Test Dust Removed After Specified Number of Cleaning Efforts by Vacuum Cleaner (Table 6a), Carpet Type (Table 6b) and Dust Amount (Table 6c)

(a) Vacuum Cleaner Comparisons

Cleaning Efforts	Least Square Means			Probability of Difference Among Vacuum Cleaners		
	Vac A	Vac B	Vac C	AC	BC	AB
1	0.260	0.268	0.142	0.0078	0.0072	0.834
2	0.455	0.439	0.232	0.0074	0.0150	0.8209
3	0.553	0.557	0.309	0.0024	0.0031	0.9583
4	0.620	0.642	0.371	0.0007	0.0006	0.6947
5	0.671	0.701	0.429	0.0004	0.0002	0.5674
6	0.709	0.755	0.481	0.0004	0.0001	0.3454
8	0.769	0.825	0.573	0.0006	0.0001	0.2116
10	0.811	0.875	0.645	0.0012	0.0001	0.1304

Table 6b

Carpet Type Comparisons

Cleaning Efforts	Least Square Means		Probability of Difference Between Carpet Types
	Sculptured	Short-pile	
1	0.192	0.256	0.0306
2	0.329	0.422	0.1085
3	0.443	0.503	0.2822
4	0.529	0.560	0.5316
5	0.598	0.602	0.9304
6	0.657	0.640	0.6876
7-8	0.740	0.704	0.3348
9-10	0.801	0.753	0.1440

Table 6c

Dust Loading Comparisons

Cleaning Efforts	Least Square Means		Probability of Difference Between Dust Amounts
	100 G/m^2	400 G/m^2	
1	0.294	0.153	0.0006
2	0.478	0.273	0.0039
3	0.578	0.368	0.0019
4	0.644	0.445	0.0010
5	0.690	0.511	0.0010
6	0.731	0.565	0.0012
7-8	0.791	0.653	0.0022
9-10	0.834	0.720	0.0047

was removed when the 100 gram amounts were applied (Table 6c) and the differences between cleaning efficiency for the two amounts were statistically significant. (The dust amounts applied were in the range of those removed from contaminated carpets as shown elsewhere in this paper.)

There was no significant difference in dust removal between the two operators tested.

The fraction of dust removed was lower when the quantity embedded in the laboratory was higher (Table 6c). This difference was statistically significant.

Bare Floor Cleaning

Two rooms with unpainted wood floors and two with linoleum-covered floors were test cleaned with the HEPA vacuum cleaner and wet washing procedure described earlier. Results of the cleaning efforts show that for wood floors, a total of about 95% of the dust removed was removed by five vacuum cleaning efforts and the follow-up washing yielded only 2-5% of the total dust collected by both methods (Table 7). Results for the linoleum floors were markedly different with the vacuuming effects. After the second minute, these vacuum cleaning efforts were relatively unproductive, with 19-22% of the dust remaining and being removed by the wet washing. About one-fifth of the total dust collected on linoleum was not amenable to removal by the vacuum cleaner method.

DISCUSSION

There are few reports in the literature on the efficiencies of methods of cleaning carpets and bare floors. In a pilot study of methods to remove lead dust from homes near a secondary lead smelter in Toronto, Canada, a pilot testing of vacuuming of carpet and floors followed by wet shampooing was carried out in eight houses.[14] An average of 5.2 times as much lead was removed by the vacuum procedures (about 1 min/sq.m) than by the wet method. The average quantity of lead removed from all areas of the houses, including heating ducts and basement ceilings, was 8.1 grams of lead per house.

Kominsky et al.[15] found that for new carpets, embedded in the laboratory with asbestos fibers, use of HEPA filtered dry vacuum cleaners at 1.4 min/sq.m was ineffective in removing the asbestos fibers. HEPA-filtered hot water extractions operated for about 1.4 min/sq.m. reduced the level of asbestos contamination in the carpet by approximately 70%.

A pilot study of the efficiency of HEPA vacuuming and shampooing of carpets and upholstered furniture from homes near a lead smelter in Bunker Hill, Idaho was conducted.[16] The cleaning protocol involved an initial vacuuming

Table 7

Percentage of Dust Removed From Floors by HEPA Vacuum Cleaning and Follow-up Washing With Tap-Water[a]

	(Vacuum Cleaning Efforts)					
Type Surface	1st	2nd	3rd	4th	5th	Follow-up Washing
Bare Wood	62	13	5	7	9	3
Bare Wood	60	12	9	9	5	5
Bare Wood	53	18	14	4	6	4
Bare Wood	14	35	16	21	12	2
Linoleum	69	12	0	0	--	19
Linoleum	69	7	5	0	--	19
Linoleum	67	11	0	0	--	22

[a]One cleaning effort = one minute per square meter of floor.

--Fifth cleaning effort not completed because prior cleaning did not yield a detectable amount of dust.

followed by five consecutive shampooings and a final vacuuming. The total amount of lead in the carpet and furniture was determined following laboratory digestion and analysis of measured portions of those items. Samples were analyzed by graphite furnace atomic absorption. A summary of the results of this study (Table 8) indicates that the cleaning efforts for the carpets were able to remove an average of less than 8% of the lead in the carpet. For furniture with only three shampooings and no final vacuuming, an average of 18% of the lead was removed.

An extrapolation for the first carpet in Table 8 revealed that 74 additional shampooings would be needed to remove all of the lead. The total lead loading (mg/m^2) in the carpet in the homes near the smelter (average 1068, range 185-3044) was somewhat higher than the amount removed during the current study (average 418, range 8.6-1107) with some overlap.

CONCLUSIONS

Carpets removed from poorly-maintained houses containing lead-based paint sources were not able to be cleaned effectively in the laboratory by repetitive cleaning with HEPA-filtered vacuum cleaners. The lead concentration in the removed dust did not change significantly from the initial cleaning (1 min/sq.m.) to the final cleaning (total cleaning time of 10 min/sq.m.).

Table 8

Amount of Lead Removed by Vacuuming[a] and Shampooing of Carpets and Upholstered Furniture from Homes Near a Lead Smelter[18]

Item	Total Lead mg	Total Lead mg/m²	Lead Removed in First Vacuuming mg	Lead Removed in First Vacuuming %	Lead Removed in Five Shampoonings[b] mg	Lead Removed in Five Shampoonings[b] %	Lead Removed in Final Vacuuming[b] mg	Lead Removed in Final Vacuuming[b] %	Total Lead Removed mg	Total Lead Removed %
Carpet	2,246	127	100	(4.45)	185	(8.23)	19	(0.85)	304	(13.6)
Carpet	46,768	2455	67	(0.14)	797	(1.70)	117	(0.25)	981	(2.1)
Carpet	5,419	185	191	(3.52)	168	(3.10)	22	(0.41)	381	(7.0)
Carpet	51,463	3044	104	(0.20)	320	(0.62)	14	(0.03)	438	(0.9)
Carpet	4,093	231	373	(9.11)	163	(3.98)	9	(0.22)	545	(13.3)
Carpet	4,083	366	339	(8.30)	77	(1.89)	9	(0.22)	425	(10.4)
Average	1,901	1068	196	(4.29)	285	(3.25)	32	(0.33)	512	(7.9)

Table 8 (continued)

Item	Total Lead mg	Total Lead mg/m^2	Lead Removed in First Vacuuming mg	%	Lead Removed in Five Shampoings[b] mg	%	Lead Removed in Final Vacuuming[b] mg	%	Total Lead Removed mg	%
Chair	1,094	464	124	(11.3)	9.9	(0.90)	--		134	(12.2)
Chair	213	125	48.4	(22.7)	7.6	(3.57)	--		56.0	(26.3)
Couch	208	29	65.4	(31.4)	14.7	(7.07)	--		80.1	(38.5)
Chair	311	95	20.0	(6.4)	7.4	(2.38)	--		27.4	(8.8)

Table 8 (continued)

Item	Total Lead mg	Total Lead %	Lead Removed in First Vacuuming mg	Lead Removed in First Vacuuming %	Lead Removed in Five Shampooings[b] mg	Lead Removed in Five Shampooings[b] %	Lead Removed in Final Vacuuming[b] mg	Lead Removed in Final Vacuuming[b] %	Total Lead Removed mg	Total Lead Removed %
Chair	112	52	0	(0)	5.3	(4.73)	--		5.3	(4.7)
Chair	57	19	9.2	(16.1)	2.0	(3.51)	--		11.2	(19.6)
Average	353	131	44.5	(14.6)	7.8	(3.69)			52.3	(18.4)

[a]At a rate of about 1.8 minutes per m^2.

[b]Three shampooings and no final vacuuming for furniture.

For wooden floors, over 95% of the total dust removed by the combination of dry vacuuming (5 min/sq.m.) followed by wet washing was removed by the dry vacuuming. 49-75% was removed after vacuuming for 2 min/sq.m. and 65%-85% was removed after 3 min/sq.m. For linoleum, more than 75% was removed by vacuuming for 2 min/sq.m. However, little was removed in subsequent vacuuming and 20% was removed in the final wet washing step.

HEPA vacuuming of new carpets embedded with a test dust in the laboratory according to an ASTM procedure was used to determine the differences in cleaning efficiency between three commercial vacuum cleaners and two carpet types. Two of the vacuum cleaners were essentially equivalent and each removed significantly more dust than a third vacuum cleaner when used for between 4 min/sq.m. and 10 min/sq.m. Cleaning for 6 min/sq.m. was necessary to remove more than 70% of the embedded dust by the two more efficient vacuum cleaners; the third vacuum cleaning effort only removed 50% after this amount of cleaning. Cleaning efficiencies were about the same for short pile and sculptured carpets.

Cleaning by HEPA vacuuming and/or shampooing does not appear to be effective for carpets "chronically contaminated" in homes containing lead dust. For carpets with recent contamination, HEPA vacuuming for at least 6 min/sq.m. was necessary to remove over 70% of the laboratory-embedded dust. Not all commercially-available HEPA vacuum cleaners tested with laboratory-embedded dust appeared to remove equivalent amounts of the dust.

ACKNOWLEDGMENTS

Financial support for the work presented in this paper came in part from U.S. Environmental Protection Agency Grant No. V00 5035-01. The efforts of Chris Kuettner in the carpet cleaning and that of Sandy Roda and her staff in chemical analysis of the samples are appreciated. Portions of this material were initially presented at the 1989 American Industrial Hygiene Conference.

REFERENCES

1. Bornschein, R.L., Succop, P., Dietrich, K., Clark, C.S., Que Hee, S.S. and Hammond, P.B.: "The Influence of Social and Environmental Factors on Dust Lead, Hand Lead and Blood Lead Levels in Young Children", Environ. Res. 38:108-118 (1985).

2. Bornschein, R.L., Succop, P.A., Krafft, K.M., Clark, C.S., Peace, B. and Hammond, P.B.: "Exterior Surface Dust Lead, Interior House Dust Lead and Childhood Lead Exposure in an Urban Environment", Symposium on Trace Substances in Environmental Health, II, 1986, D.D. Hemphill (Ed.), University of Missouri, Columbia, pp. 322-332, 1987.

3. Bornschein, R.L., Clark, C.S., Grote, J., Peace, B., Roda, S. and Succop, P.: "Soil Lead-Blood Lead Relationship in a Former Lead Mining Town", In: Lead in Soil: Issues and Guidelines, B.E. Davies and B.G. Wixson (Eds.), Science Reviews Ltd., pp. 149-160, 1988.

4. Bornschein, R., Clark, S., Pan, W. and Succop, P.: "Midvale Community Lead Study", Chemical Speciation and Bioavailability 3(3/4):149-162 (1991).

5. Clark, C.S., Bornschein, R.L., Succop, P.A., Hammond, P.B., Peace, B., Krafft, K. and Dietrich, K.: "Pathways to Elevated Blood Lead and Their Importance in Control Strategy Development", International Conference on Heavy Metals, Vol. 1, S.E. Lindberg and T.C. Hutchinson (Eds.), CEP Consultants Ltd., pp. 159-161, 1987.

6. Clark, S., Bornschein, R., Succop, P., Roda, S. and Peace, B.: "Urban Lead Exposures of Children in Cincinnati, Ohio", Chemical Speciation and Bioavailability 3(3/4):163-171 (1991).

7. U.S. Department of Housing and Urban Development: "Lead-Based Paint: Interim Guidelines for Hazard Identification and Abatement in Public and Indian Housing", Washington, D.C., September 1990 (Revised May 1991).

8. Milar, C.R. and Mushak, P.: "Lead Contaminated Housedust: Hazard Measurement and Decontamination", In Chilsolm, J. and O'Hara, D.. (Eds.) Lead Absorption in Children, Urban & Schwarzenberg, Baltimore-Munich, 1982.

9. Clark, S., Bornschein, R., Ryan, J., Kochanowski, A., Succop, P. and Peace, B.: "The Cincinnati Soil-Lead Abatement Demonstration Project", In: Lead in Soil: Issues and Guidelines, B.E. Davies and B.G. Wixson (Eds.), Science Reviews Ltd., pp. 287-300, 1988.

10. Que Hee, S.S., Peace, B., Clark, C.S., Boyle, J.D., Bornschein, R.L. and Hammond, P.B.: "Evolution of Efficient Methods to Sample Lead Sources Such as Housedust and Handdust in the Homes of Children", Environ. Res., 8:77-95 (1985).

11. Statistical Analysis System (SAS) (1988).

12. American Society for Testing and Materials, Standard Laboratory Method for Evaluation of Carpet-Embedded Dirt Removal Effectiveness of Household Vacuum Cleaners, Philadelphia, PA, 1986.

13. Personal Communication, John N. Balough, The Hoover Company, September 1988.

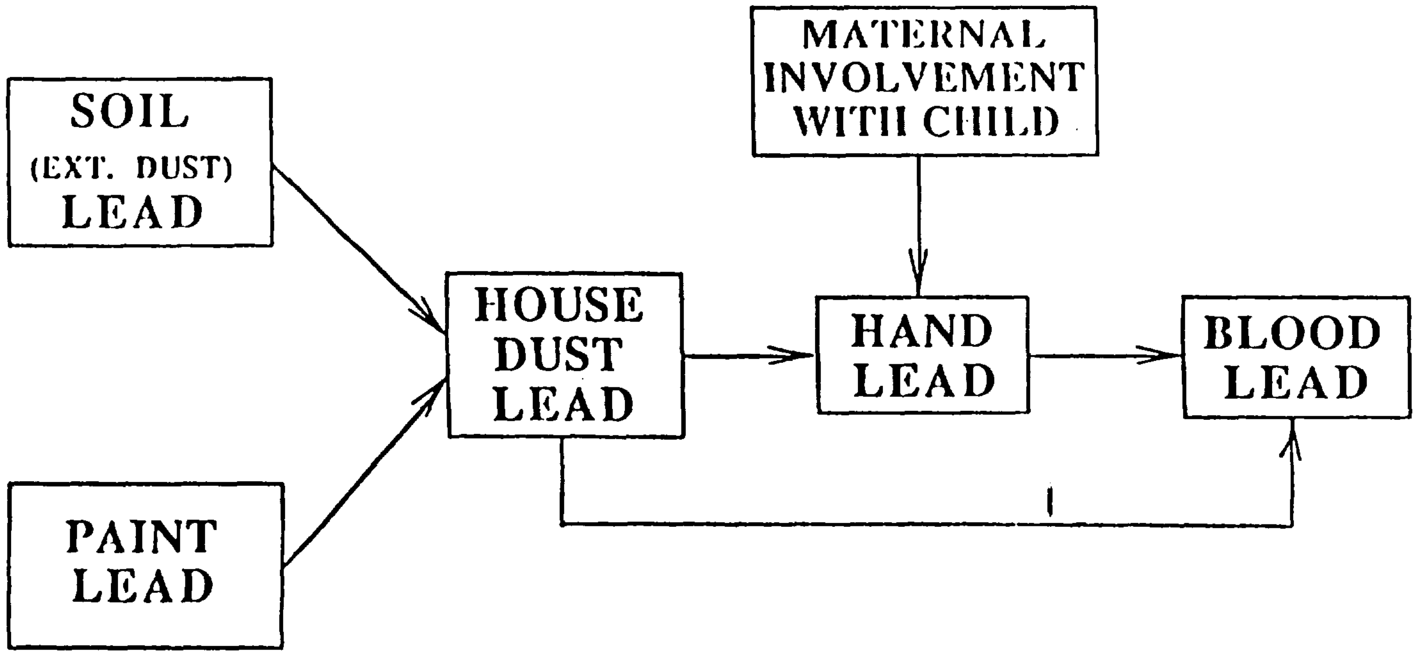
14. City of Toronto Department of Public Health: "South Riverdale Lead Reduction Program Housedust Cleaning Demonstration", Final Report Prepared by Concord Scientific Corporation and Gore & Storrie Limited in Association with South Riverdale Community Health Center, Toronto, Ontario, May 1989.

15. Kominsky, J.R.: "Evaluation of Two Cleaning Methods for the Removal of Asbestos Fibers from Carpet", Am. Ind. Hyg. Assoc. J. 51(9):500-504 (1990).

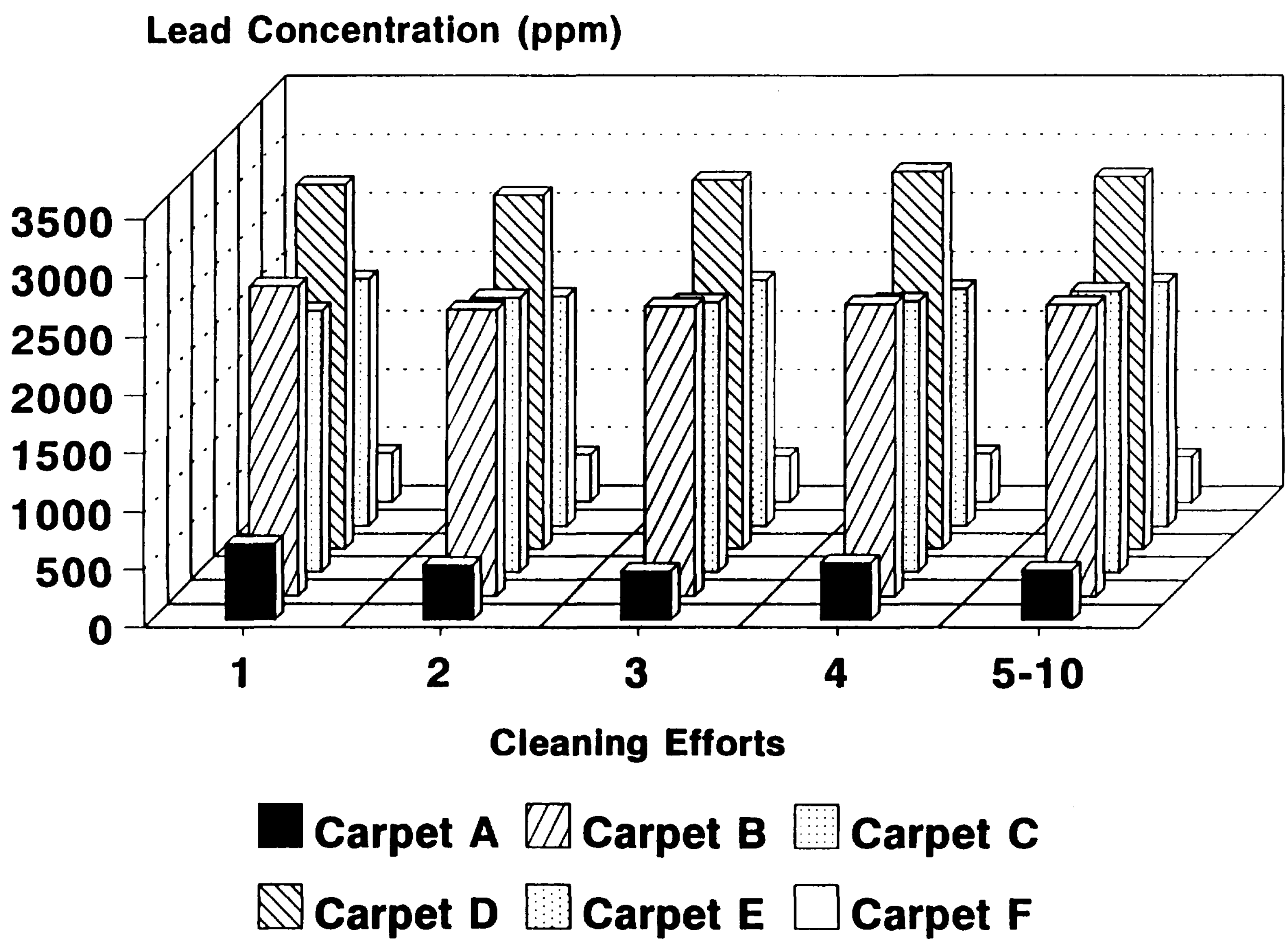
16. CH2M Hill: "Final House Dust Remediation Report for The Bunker Hill CERCLA Site Population Areas RI/FS", Document No.: BHPA-HDR-F-RO-052091, prepared for Idaho Department of Health and Welfare, Boise, Idaho, May 1991.

LIST OF FIGURES

CHILD LEAD EXPOSURE MODEL

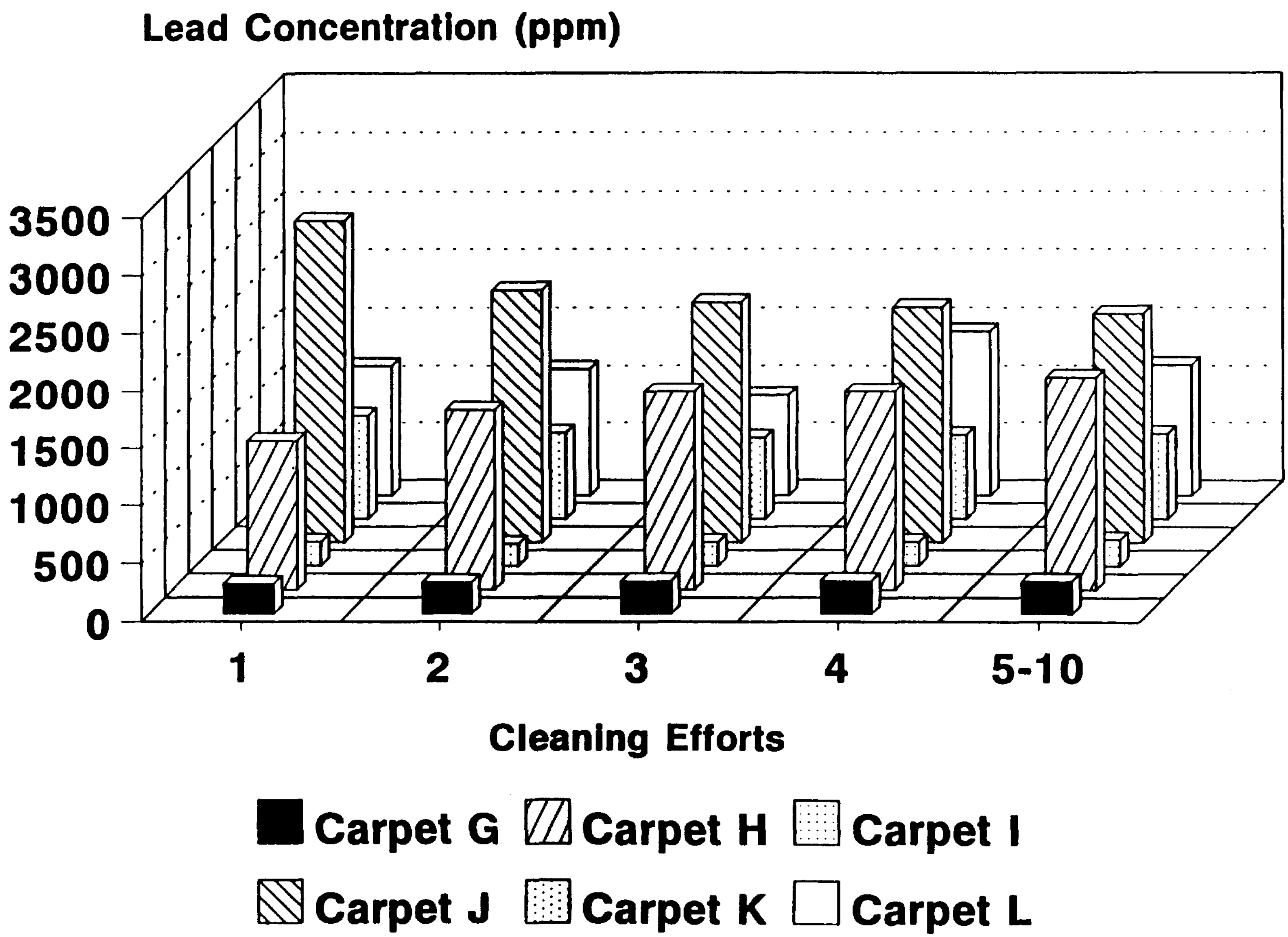


Lead Content of Vacuum Cleaner Dust After Successive Cleaning Efforts

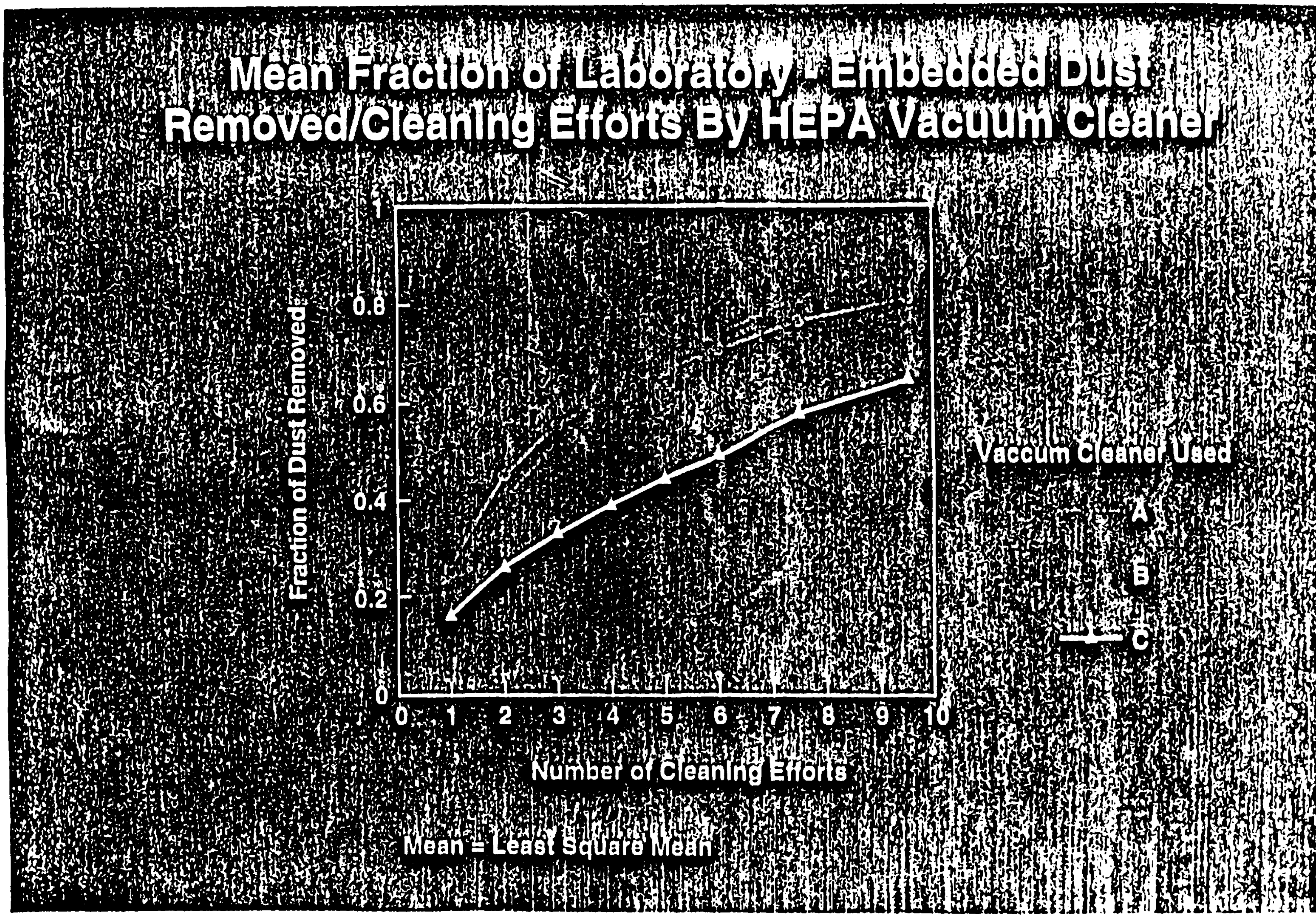


One Cleaning Effort = Cleaning at 1 min/sq m with HEPA vacuum cleaner

Lead Content of Vacuum Cleaner Dust After Successive Cleaning Efforts



One Cleaning Effort = Cleaning at 1 min/sq m with HEPA vacuum cleaner.


Mean Fraction of Laboratory - Embedded Dust
Removed/Cleaning Efforts By HEPA Vacuum Cleaner
Fraction of Dust Removed
1
0.8
0.6
0.4
0.2
0
0 1 2 3 4 5 6 7 8 9 10
Number of Cleaning Efforts
Vaccum Cleaner Used
A
B
C
Mean = Least Square Mean

APPENDIX G

Training Manual for Paint and Water Sampling

ENVIRONMENTAL MONITORING

TRAINING MANUAL FOR PAINT AND WATER SAMPLING

Section 1

What is paint and water sampling?

Water sampling is the collection and analysis of water samples from the subject residences in the Soil Project study areas. This sampling and analysis is done to determine the amount of lead in the water.

Paint sampling is the non-destructive analysis of painted surfaces on the interior and exterior of the subject residences in the Soil Project study areas. This analysis will give us an indication of the lead content of the paint on those surfaces.

Section 2

Why do we care about lead in paint and lead in water?

The major purpose of the research study is to determine the effect of the abatement of interior dust, exterior dust and lead contaminated soil on the blood leads of children under five years of age. In order to make an assessment of the actual impact of the various abatement strategies it is necessary to know the total exposure to other sources of lead in the subject child's environment. Lead in drinking water and lead in paint are potential immediate sources of exposure to the subject children.

Lead can contaminate drinking water in several ways. The water source can be contaminated. In this case the potential exposure would be uniform across all of the study areas because the water originates from the same pumping station and distribution system. Drinking and cooking water can also be contaminated with lead as a result of the presence of either lead pipe, copper pipe with soldered joints containing lead, or excessive lead in the faucet structures. The amount of lead dissolved from the sources in the plumbing system increases as the acidity of the water increases.

Lead content in paint within a residence has been identified as an immediate source of exposure to children, especially very young children.

Paint may either flake or chip off of wall surfaces and woodwork surfaces or it may come off in the form of fine dust from the operation of windows and any abrasion of painted surfaces. Knowledge of the lead concentration in these interior and exterior painted surfaces may assist in the explanation of blood lead concentrations in children living in the environment plus it may assist in the explanation of the rates of re-contamination of abated apartments and residential areas.

Section 3

When will paint and water sampling occur?

Paint and water sampling will occur two times during the course of the Soil Lead Abatement Demonstration Project. The first such sampling will occur in the early spring of 1990. This will be Phase 04 of the sampling phases. The second paint and water sampling will occur approximately one year after the initial sampling. That will be the spring of 1991; Phase 08 of the environmental monitoring.

Section 4

Who will perform the environmental paint and water sampling?

It is expected that the environmental monitors, who have collected the soil exterior dust, interior dust, dust fall, and handwipes will perform the paint and water sample collection. As in other interior environmental sampling, teams consisting of two individuals will visit the subject residences. Present plans call for two teams of two monitors to complete the work.

Section 5

Scheduling of paint and water monitoring.

Scheduling of the initial paint and water monitoring visit will be performed by the Subject Matters staff of the Cincinnati Soil Project. Initially the Data Management section will provide a current up to date list of subject families along with addresses and telephone numbers. Subject Matters staff will then start the scheduling of appointments probably using those families with telephones for the initial appointments. Once the families with phones or phone contacts are exhausted then the Subject Matters staff will be make home visits to do the scheduling.

After the scheduling of the initial visit, a work sheet for lead paint screening and water sampling will be filled out and forwarded to the abatement staff. The abatement staff will be responsible for owner contact. As with other environmental sampling, the resident's permission is adequate to perform the interior monitoring of the residences. Sampling in common areas and the exterior of buildings requires permission of the owner of the building. As long as the subject families agree, we can perform the paint and water sampling on the interior of the units. The exterior paint sampling will require permission from the owner.

Once the abatement staff receives the work sheets they will make an assessment of the presence or absence of paint on the exterior of the building. If there is paint present then the abatement staff person will contact the owner and ask permission to do the required sampling. The abatement staff person will complete two questions on the lead paint screening work sheet. Those two questions are: owner permission; yes or no and owner contacted by. Owner permission question is answered by circling either the "n" or the "y". The "owner contacted by section" is completed by entering the initials of the abatement staff person making the contact. When the abatement staff completes this information, the work sheets for lead paint screening and water sample collection are forwarded to the environmental monitoring teams who will then use these sheets for the collection of data in the field.

In the case of "no shows", the environmental monitoring team or teams will have the responsibility of doing their own rescheduling. This will be accomplished by either using the telephone to contact the family or by stopping in occasionally to see if the family is at home. It is expected that rescheduling will be less of a problem in Phase 04 because the children do not necessarily have to be home in order to accomplish this phase of sample collection. In fact, it would be easier if the children were not at home.

Two water samples are required in this phase of environmental monitoring. One water sample is collected at the time of the environmental visit by the environmental monitoring team. The second water sample is to be collected by the family at the beginning of the following day. One scheduling slot will be alloted to revisiting families to collect the second water sample. The same environmental monitoring team does not have to collect the second sample. It will be likely be more efficiently accomplished by whichever team happens to be in a particular neighborhood on a given day.

Section 6

The Environmental Visit

The Environmental Visit will begin with the environmental monitoring team greeting the family and explaining briefly the purpose of collecting the paint and water samples. An explanation of what will occur is also appropriate at this time. The key points to be covered in this initial explanation are : why we want to collect the sample. How the samples are collected. And most importantly, what the potential benefits are to the family. Potential benefits include the knowledge of both paint and water exposure to the family. If there is high lead content in the paint, parents who are aware of this might be more cautious about children playing on the floor or allowing paint chips or other dust to accumulate in the residence. Families with high lead content in the water could be instructed to reduce exposure by allowing the water to run a significant amount of time before using that water for drinking or cooking purposes.

At the conclusion of the explanation one team member will start the water collection process while the other team member begins the calibration of the XRF instrument. After the water collection process is initiated, and the XRF instrument is calibrated then both team members can proceed with the paint screening. At the conclusion of the visit the monitoring teams will assure that all of the equipment has been collected, the toys are collected, and balloons are distributed to the children if present. Finally a reminder that a team will return the following day to collect the second water sample is given to the family.

Section 7

Water Collection

Two water samples will be collected. Those are W-1 which is a 30 minute stagnation sample and W-2 which is an overnight stagnation sample. Stagnation samples are collected in order to provide some uniformity of samples and to determine the amount of lead which will dissolve into the water over a fixed time period. Significant quantities of lead will not dissolve in water as it runs through pipes which contain a lead source. One can only measure the amount of lead which will dissolve in the water if the water is allowed to stand in the pipes for a fixed period of time.

Two stagnation samples are collected in order to first determine what the typical exposure could be on a given day. Typically families will use water from the water system at varying time intervals during the day.

The overnight stagnation sample is collected in order to determine what the potential maximum exposure is to lead dissolved from lead sources within the plumbing system. As water stands in the plumbing system, dissolved lead reaches an equilibrium. It will not increase in concentration indefinitely.

The 30-minute stagnation sample, W-1, is collected in the following manner. The first step is to introduce fresh water into the plumbing system. This is accomplished by going to the kitchen and turning on the cold water only for a period of three minutes. If the kitchen sink is not functional then the second choice would be the sink where the family obtains drinking and cooking water. If only hot water is available at the kitchen sink, then another sink will give a better indication of a 30 minute stagnation sample. A stop watch will be provided to time the three minute interval. When the water is turned on, the stopwatch will be started. After three minutes of running the water the faucet can be turned off. At this time signs provided will be placed on all sinks and other sources of water. Including the toilet and bathtub. After the three minute drain of the water system is completed the stopwatch will be set for a 30 minute interval. If at any time during the course of the 30 minute stagnation time, someone in the apartment forgets or disregards a sign and runs water the process will have to begin again. This will include another three minute drain of the system and the start of the 30 minute stagnation period. When the timer sounds indicating the passage of 30 minutes, the monitor will go to the kitchen sink or whichever sink was selected and collect the water sample.

The water sample was collected by slowly turning on the water with the bottle under the faucet. Every attempt will be made to collect all of the water. None should be spilled into the sink. Once the water bottle is filled to the appropriate level the collection of the sample is complete. The cap will be securely placed on the water bottle and the bottle will be placed in the monitors sampling bag.

It will also be helpful to demonstrate the technique for collecting the water sample to the family member who will do the collection of the overnight stagnation sample, W-2. Explain the need to collect water without spilling or allowing the faucet to run prior to the collection of the sample.

At this time it will be necessary to make sure the water sheet collection form is complete. Collect the signs which were placed on the sinks and other water sources. Leave the appropriately marked sample bottle and instructions for the resident to collect the overnight stagnation sample.

Section 8

Paint Screening With the XRF Instrument

Paint sampling with the XRF instrument is accomplished in the following manner: The instrument must first be calibrated after the environmental monitoring team arrives at the subject residence. This calibration must occur at the beginning of each environmental monitor visit. The first step in calibration is to turn on the instrument and in the case of the XK3 press the reset button and hold it in for a period of 6-8 seconds. The work sheet should be available for the calibration procedure. The number of the instrument is entered in the space provided on the work sheet. Three readings are taken for each standard and recorded on the work sheet. No standards are the "no lead standard", the "mid-range standard", and the "high-range standard". The high-range standard is used only with the XK2, it is not necessary with the XK3.

During the initial introduction to the family several questions should have been answered. The answers to those questions will determine the location of painted surfaces to be sampled.

Paint testing will occur on surfaces in the three rooms most frequently used by subject children. The three rooms will most likely be the living room, kitchen, and bedroom. If there are no painted surfaces in the most commonly used rooms then alternative roms will be used.

After the instrument is calibrated and the location of the painted surfaces to be screened has been determined, it will be time to do the actual paint screening with the XRF instrument.

For taking readings on trimmed surfaces, it is better to select flat surfaces. Very often there are flat surfaces on base boards, window sills, and some window trim. If none of these surfaces is flat then an alternative surface might be a door. In most cases there are flat surfaces on doors. The disadvantage of doors is very often doors were initially varnished and stained when older buildings were constructed. Doors may have been the last wood surfaces in dwelling units to be painted. Therefore painted trim may provide the best opportunity to determine the maximum exposure from lead based paint. Three separate readings will be taken from the trim in the selected rooms. Once a piece of trim has been selected as a typical piece of trim in a given room three readings will be made on that piece of trim. Three separate readings may be obtained by taking one reading and then moving the instrument 4-6 inches then taking the second reading, moving the instrument again taking the final reading.

Walls are sampled in the same manner. Three separate readings are taken from a typical wall in the selected room. When moving the instrument to obtain the second and third readings it is better to not to move the instrument horizontal or vertical direction, but in some other axis. The reason for this is heights hidden in the wall behind the plaster or drywall, which give us various reading typically run in vertical or horizontal directions. Therefore if the instrument is moved in either of those directions and there happens to be a hype behind the plastered surface, then one could obtain subsequent readings which are potentially influenced by the presence of a iron or lead pipe.

After the readings are obtained with the XRF instrument, there are several other questions to be answered about the painted surfaces. We would like some assessment of the condition of the paint on the painted surfaces. By condition is meant by the physical state of the painted surface. Paint can be either very tight, adhering securely to the wall; or it could be flaking off in varying degrees. The condition code which will be entered on the work sheet is as follows:

- "1" indicates a very tight secure paint. In this condition there is no loose paint on the wall.
- "2" indicates that there is some loose paint; it may be bubbling or generally coming loose from the surface in some manner. Condition "2" is considered to be intermediate between Condition "1" and Condition "3".

"3" is paint which is actually flaking off of the wall and landing on the floor. It is a very loose peeling condition for the paint.

These condition codes should be entered for both the wall and trim surfaces in the rooms selected for paint monitoring.

The work sheet for paint screening also contains a place for indicating the use of the room. Room use should be written in this section. Examples of room use are, kitchen, bedroom, living room, hallway, bathroom, etc.

The final information needed for paint and wall screening is the sub-straight over which the paint is applied. The sub-straight of a painted surface is the kind of material over which the paint is applied. For trims or doors it could be and would very likely be wood for trim. Doors could be either wood or metal. Walls will very likely consist of paint over drywall or paint over plaster. Other painted surfaces could include painted brick, painted block or painted plaster over brick or block.

If the residents ask questions about the XRF readings the monitors should provide the requested information. It may not be necessary to give the actual readings to the residents if requested for example, it may not make a difference to a resident if the reading is 6.5 or 7 but the difference between the reading of 1 and the reading of 9 may make a difference to the resident. As a general guideline a reading of 2 or less would indicate there is little or no exposure to lead in paint for the residents. Readings between 2 and 6 might indicate moderate exposure. Readings above 6 could be defined as high exposure to lead in paint.

Two instruments will be used for paint screening, the XK2 and the XK3. The XK3 is the later model and some advantages in terms of calibration and ease of use. The XK2 has the capability of reading above 10 mg. per square centimeter. The XK3 has the capability of reading up to 10 mg per square centimeter. In those cases where the environmental monitoring team obtains readings with the XK2 of 10, then another screening of the paint with the XK2 instrument will be necessary. This could very well be accomplished during the return when the water sample W-2 is collected.

Section 9

Completion of the Environmental Monitoring Team's Day.

When the Environmental Monitoring Team returns to the Main Street facility, transfer of custody of the water samples will occur. The water samples and the accompanying data sheets will be given to the Environmental Coordinator, who will accept custody of those samples at that time. At the end of the day, water samples will be checked for pH and following that the samples will be acidified with concentrated nitric acid.

APPENDIX H

Worker Safety and Health Plan Publication

A publication:"Development and Implementation of a Safety and Health Program for Employees Involved with Residential Soil and Dust Lead Abatement and Monitoring" APPL. OCCUP. ENVIRON. HYG. 7(6), pp 398-404, June 1992.

Development and Implementation of a Safety and Health Program for Employees Involved with Residential Soil and Dust Lead Abatement and Monitoring

C.F. Thomson[A], B. Poppe[B], C.S. Clark[C], C.H. Rice[C], and D. Linz[C]
[A]Eastman Kodak Company, Health and Environment Laboratories, 343 State Street, Rochester, New York 14650; [B]Friends of the Homeless, 924 East Main Street, Columbus, Ohio 43205; [C]University of Cincinnati, Department of Environmental Health, 3223 Eden Avenue, Cincinnati, Ohio 45267-0056

The safety and health plan that was developed for the Cincinnati Soil Lead Abatement Demonstration Project is described from its development through its initial implementation, review, and revisions. This demonstration project, funded under the Superfund Amendments and Reauthorization Act, was developed to demonstrate the effectiveness of soil and dust lead abatement in inner-city neighborhoods in reducing the blood lead of young children. The project involved extensive sampling of soil, exterior and interior dust, water, paint lead, and blood lead. Abatement activities included soil excavation and replacement, debris removal, pavement cleaning, and housedust abatement by cleaning and furniture/carpet removal. Air lead concentrations were minimal and no significant blood leads were observed. Experiences described should prove to be useful to others engaged in similar lead abatement activities; the overall approach used may also prove useful in the development of safety and health plans for lead paint abatement projects. Thomson, C.F.; Poppe, B.; Clark, C.S.; Rice, C.H.; Linz, D.: Development and Implementation of a Safety and Health Program for Employees Involved with Residential Soil and Dust Lead Abatement and Monitoring. Appl. Occup. Environ. Hyg. 7(6):398-404; 1992.

Background

Residential lead contamination and its abatement are receiving increased public and private attention. The development and implementation of effective safety and health programs for workers involved in these activities is therefore of considerable interest.[1] The lead found in the soil and dust in urban areas is primarily from paint and atmospheric fallout, although mining and industrial sources[2] are also a problem in some areas. Lead-based paint was banned for use in housing in 1972[3]; however, many older homes still contain lead-based paint, and soils and dust are contaminated in many locations from residences previously painted with lead-based products. The primary source of lead in atmospheric fallout in most urban areas[4] was leaded gasoline, which was phased out beginning in the 1970s.

Exposure to lead for children living in urban areas may result from a number of sources, including the lead-based paint used during the last 100 years. During this time, natural weathering and other processes have eroded away portions of the paint, depositing it in the soil. Sanding, abrasive blasting, and chemical removal of the lead-based paint during urban housing renovation and rehabilitation produce small particles. When not properly contained, these particulates may contaminate the soil and contribute to high lead concentrations in urban dust. Once the soil becomes contaminated, weathering and the additional mechanical action from the movement of adults, children, and pets further break down the lead-containing dust. Wind, vehicular traffic, and pedestrians transport the dust throughout the neighborhoods and into residences. Children playing outdoors or indoors may then ingest the soil and dust through normal hand-to-mouth behavior; ingestion is greatest among children who exhibit pica behavior.[5]

Both the U.S. Department of Housing and Urban Development (HUD) and the U.S. Environmental Protection Agency (EPA) are in the process of investigating effective ways to abate lead from housing and soil. On April 1, 1990, HUD released interim guidelines (revised September 1990) for lead-based paint abatement procedures for public and Indian housing units around the country.[6] The plans include measuring the levels of lead on painted surfaces and determining the types of abatement that could be used. Decisions will then be

1047-322X/92/0706-398$5.00/7 © 1992 AIH

made as to what type of abatement will be most successful and which housing units require abatement.

The EPA is engaged in a soil and dust lead abatement demonstration program.[7] The Cincinnati Soil/Lead Abatement Demonstration Project is one of three research projects funded by the EPA through the Superfund Amendments and Reauthorization Act to determine the impact of soil and dust lead abatement.[8] The other two projects are located in Baltimore and Boston.[9,10]

The primary objective of the Cincinnati Soil/Lead Abatement Demonstration Project is to determine whether procedures to abate high lead concentrations in soil, exterior dust, and house dust, applied separately and in combination, are effective in reducing the blood lead levels in children up to 5 years of age. Secondary objectives of the project are to determine the effectiveness of the abatement procedures in reducing the quantity of lead on the hands of the children and in the dust at residences, and to determine the rate of recontamination of household dust and soil and the factors associated with such recontamination.

The primary housing type in the Cincinnati abatement areas is either rehabilitated or nonrehabilitated housing in satisfactory condition. In the area of the Cincinnati project, approximately one third of the children under the age of 5 are likely to have blood lead levels exceeding 25 μg/dl (the former Center for Disease Control (CDC) limit)[11] at least once per lifetime. The recently established current CDC goal calls for using primary prevention efforts such as community-wide environmental interventions and nutritional and educational campaigns to reduce levels below 10 μg/dl.[12] Interruption of the exposure pathways is thought to be the most successful means of reducing lead absorption. If the intervention is at the soil lead stage, there should be a consequent reduction of lead in urban dust.

Rationale and Methods

The health and safety program needed for the workers involved in the soil and dust lead abatement demonstration project activities and associated environmental and biological monitoring will be described in this article from its inception, through its development, implementation, and midcourse review. These workers were involved in lead-contaminated soil removal and replacement, interior and exterior dust removal, environmental sample collection and analysis, and blood collection and analysis. The abatement activities occurred at numerous sites in six inner-city neighborhoods. Soil abatement activities included some handwork involving picks, shovels, and wheelbarrows, and the use of mechanical equipment such as front-end loaders, bobcats, and dump trucks. Exterior dust abatement involved use of vacuum-assisted street and sidewalk cleaning equipment; interior dust abatement involved the use of vacuum cleaners with high efficiency particulate air (HEPA) filters, wet-mopping, and carpet and furniture removal and replacement.

The University of Cincinnati is a state university in Ohio, where occupational safety and health enforcement activities are conducted by the federal government. Consequently, its employees, including the in-house staff of the abatement project, are exempt from Occupational Safety and Health Administration (OSHA) regulations.[13] The soil abatement workers employed by outside contractors are covered under the OSHA construction standard.[14] Since lead is considered a hazardous waste, University employees are covered by the EPA Hazardous Waste Operations and Emergency Response standard, which was adopted as a companion regulation to OSHA's for the protection of public-sector employees. This standard requires a safety and health plan and an officer to monitor the plan.[15] Regulation notwithstanding, the EPA mandated the project staff to have a safety and health plan and a safety and health officer for the duration of the demonstration. Good public health policy and the University's commitment to comply with OSHA regulations also supported development of a comprehensive safety and health plan.

To prepare a safety and health plan, a committee of knowledgeable persons was gathered to review and assess the potential hazards that must be addressed. A committee was assembled because few persons alone have the knowledge that was required for writing a comprehensive safety and health plan.[16] The committee formed to write the Cincinnati Soil/Lead Safety and Health Plan encompassed the following fields of expertise: lead toxicity, safety, industrial hygiene, medicine, and construction hazards. Evaluation of existing and perceived hazards was conducted as a group process.

Comprehensive evaluation of the hazards was necessarily a lengthy process. It was recognized early that a flexible plan would be required so that newly identified hazards could be incorporated. The elements of the plan were lead exposure hazards, engineering controls, work practices, personal protective equipment, radiation, construction and safety hazards, medical surveillance, worker training, air monitoring, and laboratory audits.

Potential lead exposure for both project and contractor personnel was of concern. University of Cincinnati personnel would be collecting, processing, and testing contaminated soil and dust samples for the duration of the 3-year study. Contractor personnel would perform the abatement work on sites for limited time periods where lead levels in the soil were found to be elevated. Both groups would also be exposed to physical hazards. During collection of soil and dust samples or abatement of contaminated soil, sharp objects such as broken glass and metal may be present, posing a risk of puncture or cut for the environmental monitors and the contractors. Contractors have an additional physical hazard that exists when using heavy power tools. Because the abatement sites are located in heavily traveled urban areas, which are typically characterized with above-average crime rates and drug use, personal safety was another concern that required evaluation. Collection of the soil and dust would be performed outdoors throughout the year, raising concerns for both heat and cold stress. Finally, radiation sources exist in two analytical instruments: one was a portable X-ray fluorescence (XRF) *in situ* paint lead analyzer and the other a laboratory-based XRF instrument used for soil and dust lead analysis. All of the potential hazards were evaluated, analyzed, and addressed by the committee prior to writing and implementing the safety and health plan.

Development of the Safety and Health Plan

Development of the safety and health plan began with a brainstorming session in which potential exposures, hazards, and safety concerns were listed. From these items an initial outline of the safety and health plan was developed. Particular concerns were noted in the outline in addition to applicable OSHA standards. After the initial safety and health plan was written, internal review was performed before sending it to the EPA. The in-house reviews were performed by a Certified Industrial Hygienist, a physician, and the Project Directors. The EPA reviewed the document at two separate times during the initial writing. Comments and recommendations were specific and included items such as the use of cartridge-specific respirators as opposed to dust masks, discussions of sampling methods and instruments, and field testing procedures. The EPA took an active support role in reviewing and critiquing the document. Had this not been the case, an external review procedure would have been necessary to prevent an in-house bias and to identify omissions. The development of the plan took about 9 months and required about three person-months of full-time effort.

Content of the Safety and Health Plan

Lead Exposure Hazards

Lead was the initial hazard to be addressed. The most common routes of exposure for lead are inhalation and ingestion. Inhalation, being the primary concern for adults, was evaluated thoroughly. Monitoring, abatement activities, and sample sieving were judged to have the greatest potential to create elevated airborne lead concentrations. Ingestion is a less common exposure route in the workplace but may result from eating contaminated food, smoking contaminated cigarettes, chewing fingernails, and applying contaminated cosmetics.

The OSHA Lead Standard[17] was referenced thoroughly for compliance and control methods. Engineering controls were specified as the preferred way of reducing the potential lead dust hazards. To minimize and reduce dust inhalation, hoods were required for laboratory processing of the soil and exterior dust samples. These hoods are surveyed quarterly during the structured laboratory audit to ensure proper ventilation rates. The use of HEPA filters on the vacuum cleaners used for cleaning laboratory and field office space was another specified engineering control. Contractors were required to use HEPA-equipped vacuum cleaners during abatement.

Work practices and personal hygiene are additional methods of reducing lead exposure and other hazards. University employees working out of the field office were provided with shower and locker facilities.

Restrictions were implemented to prevent eating, drinking, smoking, applying cosmetics, chewing tobacco, or chewing gum at work sites. Environmental monitors were required to change into street clothes before entering the lunchroom.

A commercial cleaning service was utilized for the uniforms to prevent worker take-home of soil and dust. All streets and sidewalks within the abatement neighborhoods and all participating apartments were dust abated regardless of the lead levels in the dust. The lead-contaminated soil to be abated was well below the level that would classify it as hazardous waste. Therefore, the contamination of workers' clothing was expected to be similar to that associated with inner-city street and housing maintenance, gardening, and apartment cleaning activities, and no special procedures were thought to be necessary for the commercial cleaning service.

Personal protective equipment was used when engineering controls were deemed infeasible or the worker required protection from a physical hazard. Uniforms were worn by the site inspectors and environmental monitors to prevent the transport of lead-contaminated dust into the field office, personal automobiles, and homes. Soil abatement tools and equipment were kept separate from those used for replacement soil unless they were thoroughly cleaned between uses. Steel-toed safety shoes were the required footwear for the environmental monitors when collecting soil and exterior dust. The monitors were working with steel soil core collection devices and were also exposed to broken glass, etc., on the sites. Additionally, rubber gloves are required to be worn when handling the soil and exterior dust samples. This applied to both field and laboratory personnel.

Radiation

Two radiation sources exist in the instruments used for lead analysis. These instruments and the laboratories where they were located were tagged with radioactive warning signs. All laboratory personnel and other persons associated with these instruments attended courses on safety hazards conducted by both the manufacturer and the University.

Construction Safety Standards

Construction safety hazards were primarily a concern during the abatement phases of the project. Contractors used heavy equipment (front-end loaders, bobcats, dump trucks, etc.) as well as hand tools in highly populated areas, which posed a risk not only to the operator but to project personnel and neighborhood persons. Specific safeguards were required to address these needs. The work site was fenced to restrict adults, children, and animals from the abatement area. The fencing remained around the site on a 24-hour basis until activities were completed. This prevented contact with the equipment by the public and avoided disruption of the soil and dust, as well as providing additional security for the equipment left on the site overnight. Specifics concerning vehicles, hand power tools, concrete activities, etc., were addressed in the contractor safety and health plan according to OSHA Construction Standard 1926.

Medical Surveillance

A medical surveillance program included preplacement examinations, annual reexaminations, and monitoring for the effects of specific potential hazards.[17] The preplacement portion of the medical surveillance program established baseline data on each individual to better safeguard the health of the employee. An occupational/medical history was taken. Past occupational exposures were noted along with any pertinent medical history. A physical examination was performed to assess the employee's general health and fitness to perform required duties and to use air-purifying respirators. Baseline data were collected for blood lead levels. Because collection and analysis of numerous blood samples from inner-city children and adults was an integral part of the demonstration project, it was necessary to include prevention of blood-borne diseases and injuries in the training program and prudent to offer vaccination against hepatitis B to employees involved with blood collection and analysis. Finally, tetanus shots were given to any employee during the preplacement exam whose previous immunization was more than 10 years old or of unknown date. Employees covered by the medical monitoring program were the environmental monitors, site inspectors, and laboratory personnel because of their frequent exposure to the lead-containing soil. Specific medical monitoring requirements for each group are shown in Table I.

At 6-month intervals another blood lead determination was made; results were compared with previous data to detect whether changes in the levels had occurred. The annual medical examination also included an assessment to verify if the employee was still medically capable to carry out the tasks required in his/her position. Blood lead level was also evaluated at termination of employment.

There were 37 employees in the safety and health program. This included office staff, field monitors, and laboratory technicians. Twenty-seven of those employees were involved in the abatement and monitoring activities. Mean blood lead levels for these 27 employees were 2.4, 5.8, and 5.0 μg/dl for the initial, 6-month, and annual determinations, respectively, with standard deviations of 0.55, 2.39, and 1.00 μg/dl. The change from the initial value to 6-month value had a p-value of less than .0005 and the initial to 1-year value had a p-value of less than .005. These changes were not considered clinically significant. The highest blood lead value was 12 μg/dl. It was the only value of 10 or above. Blood samples were analyzed for lead using an ESA Model 3010A anodic stripping voltammeter. Details of the laboratory

TABLE I. Medical Surveillance Program by Job Type

Job Type	History/ Physical	Baseline Laboratory	Blood Lead	Respiratory Fitness	Physical Capacity	HBV Antibody Status	HBV Vaccine
Users of vacuum dust collection methods	R	R	R	R	N	N	N
Clinic or blood laboratory	r	r	N	N	N	r	r
Site inspectors	R	R	R	N	N	N	N
Environmental monitors and assistants	R	R	R	N	O	N	N
Safety inspector/ abatement coordinator	O	O	O	N	N	N	N

HBV = hepatitis B virus;
N = not applicable;
O = optional;
r = recommended;
R = required

methods and quality control and quality assurance program have been provided elsewhere.[18] The detection limit of this method is 1.4 ± 0.7 $\mu g/dl$.

Physical Hazards

Year-long environmental monitoring exposed the field personnel to various weather conditions that needed to be closely watched. When a heat alert was declared by the City Health Department, a heat stress monitoring protocol went into effect. Included in the protocol were the following elements: worker information and training, work practices, heat alert program, environmental surveillance, medical surveillance, and record keeping. Results were obtained by a series of calculations, and effective measures were taken appropriate to the findings, i.e., reduce the work day, increase consumption of fluids, stop all outdoor activities, etc.

Injury occurrence was monitored by means of an Incident Report. The report was filed immediately after an incident and then reviewed by those persons involved. Appropriate action and follow-up was taken relevant to the incident.

Worker Training

Training was needed for hazard recognition and to assure proper use of protective equipment and other control measures. Several training programs were developed and implemented during the Lead Demonstration Project. A general health and safety training session was given for laboratory and field personnel. This covered general laboratory practices, chemical and physical hazards, legal rights and responsibilities, personal protective equipment, emergency response, hazard control, work practices and procedures, and medical surveillance. A lead hazard session was provided for all employees. This session encompassed information on how lead enters the body, health effects, and ways to reduce exposure. A first aid program given by the Red Cross was required for field monitors. Each field crew has at least one person trained in first aid. Heat and cold stress training was given to all field monitors. The heat stress protocol was also reviewed at this session. The Red Cross also provided CPR training and a lifting techniques and back injury prevention program for those employees required to lift heavy objects. Workers involved in blood collection also received training in AIDS awareness, phlebotomy work practices, and medical surveillance. Supervisors were required to attend all of the training sessions. Training sessions were performed for short durations of time (1 to 5 hours) and in small groups with interactive discussions. This approach to training, which actively involves the trainees, was used to foster learning through participation.[19] Training occurred annually or more often if the work activity repeated at more frequent intervals. For example, training of blood collection clinic staff occurred five times over about a 26-month period. The total amount of training ranged from about 5 to 15 hours for each worker on an annual basis.

Air Monitoring

Air sampling strategies were developed to obtain an initial determination of levels of airborne lead at each work site. Both personal and area air samples were collected. Analyses were performed in an American Industrial Hygiene Association accredited laboratory. Levels must be maintained below the OSHA permissible exposure limit (PEL) of 50 $\mu g/m^3$ and preferably below the action level of 30 $\mu g/m^3$.[17] Provisions were also made to include any new or changed activities for additional monitoring if airborne lead concentration might approach the action level.

Area and personal air monitoring was performed at a temporary laboratory used for a field office and during soil sieving and preparation at the beginning of the project. The mean concentration of lead found during activities exposed employees to less than 1 $\mu g/m^3$. When the soil processing laboratory was then moved to its permanent location, sampling was performed again, as required in the safety and health plan. The mean concentration found at this facility was less than 3 $\mu g/m^3$. During the initial vacuum cleaner performance, air levels were below 0.25 $\mu g/m^3$. The lead levels found in the laboratory facilities were well below the OSHA PEL and action level and therefore are in compliance.

At the time of the development of this safety and health program, little information could be located in the literature on air lead levels during similar activities elsewhere. Municipal street cleaners in Cincinnati, using the dustier mechanical broom-type sweepers, were previously found to be exposed to a geometric mean air lead concentration of 3.2 $\mu g/m^3$ (maximum 6.6 $\mu g/m^3$).[20] More recently, extensive monitoring of air lead exposure during interior dust abatement at an interior residential dust abatement pilot program in a neighborhood near a secondary lead smelter in Toronto, Canada, was reported by others.[21] Air lead concentrations were determined from both personal and area air samples collected before, during, and after abatement activities in eight houses. Airborne dust concentrations were also determined from the area samples. Results of the area monitoring revealed that airborne lead concentrations were all below the OSHA PEL of 50 $\mu g/m^3$, with the highest value being 9.2 $\mu g/m^3$. The average airborne lead concentration was somewhat higher during abatement (0.76 $\mu g/m^3$) than before (0.31 $\mu g/m^3$) or after (0.14 $\mu g/m^3$). Area dust concentrations followed a similar pattern, with the highest level (1.3 $\mu g/m^3$) occurring during abatement. This value was less than 10 percent of the OSHA nuisance dust limit of 15 $\mu g/m^3$. Personal air samples revealed somewhat higher levels than area samples with a mean concentration during duct cleaning of 2.9 $\mu g/m^3$ (range: 0.76 to 4.39 $\mu g/m^3$; standard deviation: 1.38 $\mu g/m^3$), which was four times the mean area sample concentration. Concentrations during the house cleaning were somewhat higher (4 $\mu g/m^3$, range: <0.1 to 25.72 $\mu g/m^3$, standard deviation: 7.40 $\mu g/m^3$). The three highest values (13.0 to 25.7 $\mu g/m^3$) occurred during basement cleaning before precautions were taken to minimize dust created by moving items laden with lead-containing dust.

Project Audits

Laboratory, field, and abatement audits were implemented as measuring devices for compliance. Both the laboratory (sample processing and analysis) and field (sample collection) audits were required on a quarterly basis. Compliance with the safety and health plan was checked, hood flow velocities measured, and work practices observed. Recommendations, if needed, were recorded and forwarded to the appropriate personnel and the Project Directors with an expected completion date specified. Abatement audits were required on a weekly basis during abatement activities conducted in the third project year. This time period allowed for timely feedback and implementation of recommendations. All audits were performed by the Safety and Health Officer or an appointed designee. All forms were developed by the Safety and Health Officer and revised by the multidisciplinary team. Documentation for the contents and specification for instrument use were developed to help assure uniform use over the course of the project. Over 50 audits were performed.

Review of the Plan

After the first cycle of abatement activities had been completed, postabatement review sessions were conducted with supervisors, site inspectors, and other employees. These discussions revealed a need for revisions to the safety and health plan. The Project Directors and the Safety and Health Officer spoke with each site inspector separately to review safety and health aspects of the just-completed abatement. A composite list was assembled, which detailed the revisions that were needed. Those items were explored and discussed with various project staff to find feasible solutions. Once solutions were found, revisions were made to the safety and health plan. Completed revisions were reviewed by a Certified Industrial Hygienist and by the Project Directors, and upon their approval the safety and health plan was sent to the EPA.

Plan Revisions

Clearer lines of authority needed to be established between University and contractor employees to promote good communications as well as thorough understanding of abatement activities. As a result, project staff were briefed on procedures for the exchange of health and safety information from the Health and Safety Officer to outside contractors (Figure 1). Contractors were also briefed on the communication lines to achieve smooth transmission of information. Training of the contractors about lead exposures and hazards was needed to reduce apprehension about exposure. This arose from a prior decision *not* to include training in lead exposure hazards as a major part of the outside abatement contractor's worker training program because of the minimal exposure thought to be involved. The lack of the lead exposure training resulted in the workers becoming worried about the potential lead exposure risks of their job activities. A training program was developed and implemented that included lead toxicity, anticipated levels of exposure for the contractors and its potential impacts, and good work practices to prevent worker take-home of soil and dust and to prevent contamination of areas adjacent to the work site. Workers responded well to the training, and concerns about their risks to lead exposure were reduced to more appropriate levels.

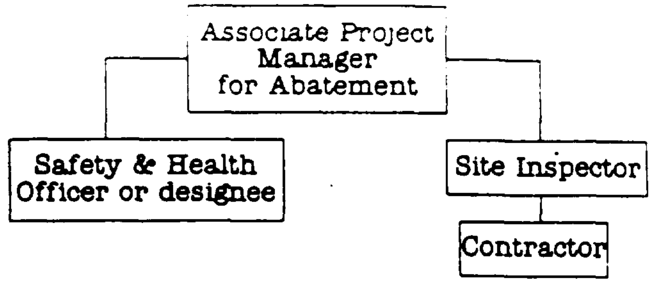


FIGURE 1. Flow diagram of site communication for nonemergency matters.

After two incidents during the 1989 abatement phase (a hydraulic line leak and a gasoline spill), emergency procedures were developed for spill management and to prevent possible injury. Revisions in the abatement contracts specified that the contractor have a plan in place for those types of emergencies.[22] These plans were checked during weekly abatement audits by the Safety and Health Officer during the periods of on-site active abatement.

After receiving reports from the environmental monitors about the noise level of the vacuums being used, sound-level monitoring was performed. During operation, the two vacuum cleaners projected 87 and 93 dBA, respectively. Therefore, a hearing conservation program was written and implemented.[23] Sections of the program included: hazard assessment, audiometric testing of employees, monitoring specifications, training, and personal protective equipment. A safety alert was also posted for employee review, and vacuum cleaners were tagged with precautions to reinforce the hearing conservation program.

Summary and Conclusion

A stepwise approach in the development and implementation of a safety and health plan is presented and used in constructing a program for employees involved in lead abatement. Persons knowledgeable in industrial hygiene, safety, medicine, construction hazards, and lead abatement participated in the development of the Safety and Health Plan for the Cincinnati Soil/Lead Abatement Project. Since few individuals possess the knowledge of each of these areas, assembling a comprehensive team was an important first step.

Once a team had been assembled, a thorough assessment of potential and existing hazards was made. Evaluation of each hazard and any measure that could control, reduce, or eliminate the hazard was discussed. Once the most efficient and cost-effective measures to control the hazards were identified, the safety and health plan was written.

The safety and health plan includes sections concerning engineering controls, personal protective equipment, training, medical surveillance, and review procedures. Each of these sections included a comprehensive approach to reduce employee hazard exposure.

Training involved initial and periodic updates to keep employees well informed and knowledgeable on any potential exposures resulting from their work. This training was provided in a small group setting in which interactive participation was emphasized. New employees were trained prior to starting work, which provided an excellent opportunity to review existing employees on the material being presented.

A review and update of the safety and health plan at regular intervals ensured a working, practical approach. Review occurred at least annually, and more often when events dictated. This critical step included a complete review of all activities that occurred during the year. Revisions were made to incorporate suggestions and to address newly recognized potential hazards and regulation updates.

In conclusion, the Safety and Health Plan for the Cincinnati Soil/Lead Project proved to be an effective, working document for the staff and employees. With the implementation of the yearly discussion and review suggestions, this program should also provide useful material for the development of an effective model for lead paint abatement safety and health plans.

References

1. U.S. Department of Housing and Urban Development: Comprehensive and Workable Plan for the Abatement of Lead Based Paint in Privately Owned Housing: A Report to Congress. Washington, DC (December 7, 1990).
2. Faulk, H.; Ing, R.T.: The Centers for Disease Control Perspective of Lead in Soil. In: Lead in Soil: Issues and Guidelines, pp. 55–64. B.E. Davies and B.G. Wixson, Eds. Science Reviews Limited (1988).
3. Lead Based Paint Poisoning Prevention Act (1971).
4. Chaney, R.L.; Mielke, H.W.; Sterrett, S.B.: Speciation, Mobility and Bioavailability of Soil Lead. In: Lead in Soil: Issues and Guidelines, pp. 105–129. B.E. Davies and B.G. Wixson, Eds. Science Reviews Limited (1988).
5. Bornschein, R.L.; Succop, P.; Dietrich, K.; Clark, C.S.; Que Hee, S.S.; Hammond, P.B.: The Influence of Social and Environmental Factors on Dust Lead, Hand Lead and Blood Lead Levels in Young Children. Environ. Res. 38:108–118 (1985).
6. U.S. Department of Housing and Urban Development: Office of Assistant Secretary for Public and Indian Housing. Lead-Based Paint: Interim Guidelines for Hazard Identification and Abatement in Public and Indian Housing. Washington, DC (September 1990).
7. Superfund Amendments and Reauthorization Act 9186, Section I-ii(b) (6).
8. Clark, S.; Bornschein, R.; Succop, P.; Peace, B.; Ryan, J.; Kochanowski, A.: The Cincinnati Soil-Lead Abatement Demonstration Project. In: Lead in Soil: Issues and Guidelines, pp. 105–129. B.E. Davies and B.G. Wixson, Eds. Science Reviews Limited (1988).
9. Farrell, K.: Baltimore Soil-Lead Project. In: Lead in Soil: Issues and Guidelines, pp. 281–285. B.E. Davies and B.G. Wixson, Eds. Science Reviews Limited (1988).
10. McIntyre, D.; Mahoney, M.: Boston Soil Lead Project. In: Lead in Soil: Issues and Guidelines, pp. 247–252. B.E. Davies and B.G. Wixson, Eds. Science Reviews Limited (1988).
11. Centers for Disease Control: Preventing Lead Poisoning in Young Children, a Statement by the Centers for Disease Control, Atlanta, GA (1985).
12. Centers for Disease Control: Preventing Lead Poisoning in Young Children, U.S. Public Health Service, Atlanta, GA (October 1991).
13. Code of Federal Regulations: Title 29, Part 1910, Section 5.
14. Code of Federal Regulations: Title 29, Part 1926, Section 12.
15. Code of Federal Regulations: Title 29, Part 1910, Section 120.
16. Caparaz, A.; et al.: Development and Pilot Evaluation of a Health and Safety Training Program for Foundry Workers. Appl. Occup. Environ. Hyg. 5(9):595–603 (1990).
17. Code of Federal Regulations: Title 29, Part 1910, Section 1025.
18. Roda, S.M.; Greenland, R.D.; Bornschein, R.L.; Hammond, P.B.: Anodic Stripping Voltammetry Procedure Modified for Improved Accuracy Blood Lead Analysis. Clin. Chem. 34:563–567 (1988).
19. Smith, B.J.; Delahaye, B.L.: How To Be an Effective Trainer, 2nd ed. Wiley Professional Development Programs. John Wiley & Sons, New York (1987).
20. Bohan, P.; Hertzberg, V.; Burg, W.; Clark, S.: Airborne Lead, Dust, and Asbestos-like Fibers in Mechanical Street Cleaner Environments and an Evaluation of Some Contributory Factors. Appl. Ind. Hyg. 6(1):54–58 (1991).
21. Toronto Department of Public Health: South Riverdale Lead Reduction Program, Housedust Cleaning Demonstration, Final Report. Toronto, Ontario, Canada (October 1988).
22. Code of Federal Regulations: Title 29, Part 26.59.
23. Code of Federal Regulations: Title 29, Subpart D, Part 1926.52.

Received 9/18/91; accepted 1/14/92

APPENDIX I

Agenda for Contractor Training

AGENDA
CONTRACTOR TRAINING
July 29, 1991

Why Are You Here? — Schmitgen

Rights and Responsibilities — Schmitgen
1. What are your R & R?
2. Lead Modes of Transmission
3. OSHA Action Levels

Hazard Recognition — McElroy
1. Activity
   Hazard Control
   1. debris
   2. air
   3. noise
   4. animals
   5. people
   6. traffic
   7. heat
2. Health Effects
   1. Heat Stress, Heat Exhaustion, Heat Stroke

Hazard Control — McElroy
1. Monitor Area
2. Safe Work Practices
   1. lifting
   2. forklifts
   3. slips, trips and falls
   4. secure work area

Personal Protective Equipment - PPE — Schmitgen
1. Hearing Protection
2. Respiratory Protection
3. Protective Clothing
4. Other PPE

Decontamination — McElroy
1. Truck
2. Equipment
3. Shoes

Emergency Response — Schmitgen
1. List of Important Names

APPENDIX J

Interior and Exterior Safety & Health Audits: Forms Used & Dates Performed

UC LEAD DEMONSTRATION PROJECT

LABORATORY SAFETY AUDIT

Date of Visit:

Location:

Supervisor:

Persons Observed:

1. General description of use:

Chemicals used:

2. PPE:

Lab coat	yes	no	n.a.
Gloves	yes	no	n.a.
Safety glasses/goggles	yes	no	n.a.
Single-use respirators	yes	no	n.a.
Workpants/coveralls	yes	no	n.a.
Safety shoes	yes	no	n.a.
Acid resistant PPE	yes	no	n.a.

Comments:

3. Signs:

Lead hazard label:			
Entrance	yes	no	n.a.
Waste containers	yes	no	n.a.
Sample containers	yes	no	n.a.
Biological hazard label:			
Entrance	yes	no	n.a.
Waste containers	yes	no	n.a.
Refrigerator	yes	no	n.a.
Transport containers	yes	no	n.a.
Chemical hazard labels:	yes	no	n.a.
Personal hygiene:			
No smoking	yes	no	n.a.
No eating or drinking	yes	no	n.a.
Hand washing	yes	no	n.a.

Comments:

4. Chemical storage:

Storage instruction given	yes	no
Organic/inorganic mix	yes	no
Proper cabinets	yes	no
Incompatibilities	yes	no
Personnel familiar with MSDS	yes	no
Flammable storage	yes	no
All containers labeled	yes	no

Comments:

5. Disposal.

Broken glass receptacle	yes	no	n.a.
Soil/dust receptacle	yes	no	n.a.
Hazardous materials	yes	no	n.a.
Biological waste	yes	no	n.a.

Comments:

6. Emergency.

First Aid kit	yes	no	inadequate
Fire extinguisher	yes	no	inadequate
Notification list	yes	no	inadequate
Spill clean-up list	yes	no	inadequate
Eye wash station	yes	no	inadequate
Telephone	yes	no	inadequate

Comments:

7. Housekeeping:

Food/drink	yes	no	
Orderly work area	yes	no	
Clean restrooms	yes	no	n.a.
Clean shower rooms	yes	no	n.a.

Comments:

8. Other comments:

9. Recommendations:

Denis Boudreau

______________________________ ______________________

Investigator Date

Report distributed to:

______Bill Menrath
______Sandy Roda
______Linda Conway-Mundew
______Scott Clark
______Bob Bornschein

Date:________________

4/90/DB

Laboratory Hood Safety Audit
General Purpose Laboratory Hood

Date ___/___/___ Hood ____________ Location ______________
U.C. ID# __________ Room __________
Investigator ______________________

Date of last review ___/___/___ Date of last maintenance ___/___/___

HOOD TYPE: 1.Dry box of glove___2. Vertical sash___3. Horizontal sash___
4. Laminar flow___.

Materials used in hood and degree of hazard.

Is hood near door/window or exit?

Is hood in high traffic area?

Hood damage?

Lights work properly?

U.V. lights work properly?

Electrical receptacles inside hood?

Airflow grille clogged?

Sharp corners or edges present?

Materials and equipment 6" from face of hood?

Comments:

HOOD AUDIT

DATE ____________ HOOD ____________ ADDRESS ________________________

U.C. ID# ____________

audit by [illegible]

Full open

Height(ft) = ____________

Width(ft) = ____________

Avg Vel=fpm	**#DIV/0!**
Vel (cfm)=	**#DIV/0!**

Area(ft^2) = 0.00
Max Vel (fpm) 0.00
20% AvgV= #DIV/0!

Min Vel fpm	**0.00**

Half open

Height(ft) = ____________

Width(ft) = ____________

Avg Vel=fpm	**#DIV/0!**
Vel (cfm)=	**#DIV/0!**

Area(ft^2) = 0.00
Max Vel(fpm) 0.00
20% Avg V= #DIV/0!

Min Vel fpm	**0.00**
Rec Min V=>	**#DIV/0!**
Rec Max V=<	**#DIV/0!**

Working Avg Vel=fpm #DIV/0!

UC Lead Soil Demonstration Project

INTERIOR DUST SAFETY AUDIT

Date:
Location:
Site:
Investigator:
Contractor:
Supervisor/Foreman:
Site inspector:

1. General description of site and work tasks observed.

Equipment on site:

Has contractor attended safety training?	yes no n.a.
Site Entry/Exit log	yes no n.a.

Comments:

2.PPE

Eye and face protection	yes no n.a.
Head protection	yes no n.a.
Foot protection	yes no n.a.
Protective clothing / gloves	yes no n.a.
Moving of furnishings, carpet and equipment	
Minimum of two (2) persons	yes no n.a.
Safe lifting methods	yes no n.a.
Entrances, stairway and passageway evaluated prior to items moved	yes no n.a.

Comments:

3. Medical services

Are telephone numbers of physician, hospital or ambulance conspicuously posted?	yes no n.a.

Comments:

4. Site control

Contamination control

Transport and handling of contaminated items	
Furnishings	yes no n.a.
Water	yes no n.a
Dust	yes no n.a.
Security maintained on removed furnishings prior to disposal	yes no n.a.
Manifest system in effect	yes no n.a.

Comments:

5. Housekeeping

Is site maintained in an orderly fashion?	yes no n.a.
Work area, passageway and stair areas kept clear	yes no n.a.
Dust containers equipped with covers	yes no n.a.

Comments:

6. Emergency response

Emergency contact list available?	yes no n.a.
Fire protection and prevention;	
Electrical	yes no n.a.
Internal combustion engines (exhaust)	yes no n.a.
Smoking in designated area only?	yes no n.a.
Flammable bases or liquids?	yes no n.a.

Comments:

7. Motor vehicles, and tools

Motor vehicle	yes no n.a.
Hand and power tools	yes no n.a.

Comments:

8. Safety regulations

(1.) Eating or smoking on site is prohibited except in specifically designated areas.

(2.) Safety equipment and protective clothing shall be worn at all times as specified.

(3.) Employees shall wash hands and face before eating, drinking or smoking.

(4.) Regulations on washing and removing boots, coveralls and hard hats shall be observed.

(5.) All accidents, regardless of severity shall be reported to the immediate Supervisor, including damage to property.

(6.) Horseplay, fighting, teasing, or practical jokes on site are all strictly forbidden.

(7.) Use of defective tools or equipment is strictly prohibited.

(8.) Employees shall never stand under truck loads in any position and shall prevent other employees or pedestrians from doing so.

(9.) Employees should check the equipment before each use to assure that all guards are in place and that the work area is well-maintained and safe.

(10.) Work areas should be kept free of all oil and any substances which are slippery.

(11.) All the equipment shall be removed from the site at the end of each work day or properly stored in accordance with Section J (a).

(12.) No one is to report for work in possession of or under the influence of intoxicants or drugs.

(13.) All trash must be placed in appropriate receptacles and disposed of in accordance with City ordinances.

(14.) All employees shall receive a copy of this Plan or have access to this document at their place of work. The Contractor shall brief the employees about this Plan and its availability before work

Comments:

9. Other

Illumination

Minimum of ten (10) foot-candles yes no n.a.

Comments:

Sanitation

Potable water yes no n.a.

Toilet facilities yes no n.a.

Washing facilities yes no n.a.

Comments:

Occupational noise exposures yes no n.a.

Comments:

Electrical hazards yes no n.a.

Comments:

[illegible] Recommendations

Denis Boudreau

______________________________ ______________________

Investigator Date

Report distributed to:

______Bill Menrath
______Sandy Roda
______Linda Conway-Mundew
______Scott Clark
______Bob Bornschein

Date ______________

UC Lead Soil Abatement Demonstration Project

EXTERIOR DUST SAFETY AUDIT

Date:
Location:
Site
Investigator:
Contractor:
Supervisor/Foreman:
Site inspector:

1 General description of site and work tasks observed.

Equipment on site:

Has contractor attended safety training? yes no n.a.
Comments:

2 PPE

Eye and face protection	yes no n.a.
Head protection	yes no n.a.
Foot protection	yes no n.a.
Protective clothing / gloves	yes no n.a.

Comments:

3 Medical services

Are telephone numbers of physician, hospital or ambulance conspicuously posted? yes no n.a.

Is there a first aid kit? yes no n.a.
Is the first aid kit adequately stocked? yes no n.a.
Comments:

4 Site control

Dust control yes no n.a.
Vehicle and pedestrian traffic
Is there at least one traffic lane open at all times? yes no n.a.

Barriers, signs and detours

Is there adequate signage?	yes no n.a
Danger	
Caution	
Exit	
Safety instruction	
Direction	
Traffic	
Accident prevention tags	
Are flaggers using proper signals?	yes no n.a.
Are barricades effective?	yes no n.a.

Comments:

5. Housekeeping

Are scrap lumber and combustibles properly controlled.	yes no n.a.
Are proper waste containers with lids used?	yes no n.a.
Is site maintained in an orderly fashion?	yes no n.a.

Comments:

6. Emergency response

Emergency contact list available?	yes no n.a.
Fire protection and prevention;	
Electrical	yes no n.a.
Internal combustion engines (exhaust)	yes no n.a.
Smoking in designated area only?	yes no n.a.
Flammable bases or liquids?	yes no n.a.

Comments:

7. Motor vehicles, mechanized equipment and tools

Motor vehicle	yes no n.a.
Off road vehicles	yes no n.a.
Material handling equipment	yes no n.a.
Hand and power tools	yes no n.a.

Comments:

8 Safety regulations

(1.) Eating or smoking on site is prohibited except in specifically designated areas.

(2.) Safety equipment and protective clothing shall be worn at all times as specified

(3.) Employees shall wash hands and face before eating, drinking or smoking.

(4.) Regulations on washing and removing boots, coveralls and hard hats shall be observed.

(5.) All accidents, regardless of severity shall be reported to the immediate Supervisor, including damage to property.

(6.) Horseplay, fighting, teasing, or practical jokes on site are all strictly forbidden.

(7.) Use of defective tools or equipment is strictly prohibited.

(8.) Employees shall never stand under truck loads in any position and shall prevent other employees or pedestrians from doing so.

(9.) Employees should check the equipment before each use to assure that all guards are in place and that the work area is well-maintained and safe.

(10.) Work areas should be kept free of all oil and any substances which are slippery.

(11.) All the equipment shall be removed from the site at the end of each work day or properly stored in accordance with Section J (a).

(12.) No one is to report for work in possession of or under the influence of intoxicants or drugs.

(13.) All trash must be placed in appropriate receptacles and disposed of in accordance with City ordinances.

(14.) Vehicular speed is not to exceed 5 MPH on the site to minimize dust generation.

(15.) Trucks or any other vehicle carrying Contractor's supplies, tools, etc., may park at the work site; however, they must be decontaminated and inspected prior to leaving the site.

(16.) All employees shall receive a copy of this Plan or have access to this document at their place of work. The Contractor shall brief the employees about this Plan and its availability before work commences.

Comments:

9. Other

Illumination yes no n.a.

Comments:

Sanitation

Potable water yes no n.a.

Toilet facilities yes no n.a
Washing facilities yes no n.a

Comments:

Occupational noise exposures yes no n.a.

Comments:

Electrical hazards yes no n.a.

Comments:

9. Recommendations:

Denis Boudreau

______________________________ Date ______________________

Investigator

Report distributed to:

______Bill Menrath
______Sandy Roda
______Linda Conway-Mundew
______Scott Clark
______Bob Bornschein

Date:________________

HEALTH AND SAFETY AUDITS
1989

Lab Audits

Date	Location	Room
6/29/89	Main Street	
12/29/89	Main Street	
4/19/89	Kettering	204
6/30/89	Kettering	309
10/4/89	Kettering	309
3/15/89	Kettering	322
10/31/89	Kettering	322
3/15/89	Kettering	329
6/30/89	Kettering	329
10/6/89	Kettering	329
11/2/89	Kettering	329
4/19/89	Kettering	407
5/16/89	Kettering	407
6/30/89	Kettering	407

HEALTH AND SAFETY AUDITS
1990

	Date	Location
Lab	6/21/90	Wherry Hall G-07
	11/7/90	Wherry Hall G-07
	8/17/90	3333 Vine Street
	6/5/90	EPA 108
	11/28/90	EPA 108
	11/28/90	EPA 110
	1/3/90	Main Street*
	1/12/90	Main Street*
	2/5/90	Main Street*
	2/12/90	Main Street*
	4/10/90	Main Street
	7/17/90	Main Street
	10/23/90	Main Street
	1/22/90	Kettering 204
	2/20/90	Kettering 309
	4/19/90	Kettering 309
	6/30/90	Kettering 309
	3/30/90	Kettering 322

*Hood Audit Only

Clinic	6/28/90	Main Street
	11/20/90	Main Street

Interior Dust	8/17/90	537 E. 13th Street
	8/22/90	1824 Race Street

Exterior Dust	8/27/90	Dandridge
	9/6/90	Findlay
	9/14/90	Findlay
	9/20/90	Price Hill
	10/4/90	Lower Price Hill
	10/5/90	Bolivar Alley
	10/17/90	Pendleton
	10/17/90	Dandridge
	10/25/90	Findlay
	10/31/90	Findlay

HEALTH AND SAFETY AUDITS
1991

	Date	Location	
Lab	6/21/91	Main Street	
	6/24/91	EPA	108
	6/24/91	EPA	110
	7/2/91	Med. Science Bldg.	6260
	6/26/91	3333 Vine Street	201
	6/27/91	Wherry Hall	G-07
Clinic	NONE		
Interior Dust	7/10/91	Glencoe	
	7/15/91	Glencoe	
	7/25/91	Glencoe	
	8/1/91	Glencoe	
Exterior Dust	7/3/91	Glencoe/Mohawk	
	7/31/91	Glencoe	
	8/28/91	Mohawk	
Field Safety	6/21/91	Glencoe	
	6/26/91	Glencoe	
	6/28/91	Glencoe	
	7/2/91	Findlay	
	7/10/91	Glencoe	
	7/16/91	Pendleton	
	7/24/91	Glencoe/Mohawk	
	8/2/91	Dandridge	
	8/22/91	Pendleton	

Appendix K

Door Mat Placement, Sampling and Removal Sequence

APPENDIX K

INTERIOR DOOR MAT PLACEMENT AND SAMPLING SEQUENCES

Phase	Mat Placed	Mat Removed	Mat Sampled	Approximate Length of Time Mat in House
01	One	---	One	Mat sampled after less than 1 hr in residence
02	Two	One	One	Two months in residence (during Interior and Exterior Abatement in Area A and Interior Abatement in Area B)
03	---	---	Two	Three months in residence (Post-Abatement for Areas A and B)
05	Three	Two	Two	Ten months in residence (Post-Abatement for Areas A and B)
06	Four	Three	Three	Two months in residence (during Ext. Abatement in Area B)
07	---	---	Four	Three months in residence (Post-Abatement in Area B)
09	---	---	Four	Ten months in residence (Post-Ext. Abatement in Area B)